EFFECTS OF STRENGTH ON SELECTED PSYCHOMOTOR PERFORMANCES
OF HEALTHY AND FRAIL ELDERLY FEMALES

THESIS

Presented to the Graduate Council of the
University of North Texas in Partial
Fulfillment of the Requirements

For the Degree of

MASTER OF SCIENCE

By

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August, 1993
Meyer, Rhonda D. Effects of Strength on Selected Psychomotor Performances of Healthy and Frail Elderly Females. Master of Science (Kinesiology), August, 1993, 75 pp., 4 tables, 1 illustration, 79 titles.

The purpose of this study was to compare muscle strength and psychomotor performance measures in healthy (n = 18) and frail (n = 21) groups of elderly women utilizing movements requiring various amounts of strength and ballistic action. Subjects were community-dwelling females ranging in age from 66-92 years. Evaluations of functional assessment of motor skills and grip strength occurred. Psychomotor performance was measured through production of aiming movements on a Digitizing Tablet. RT, MT, and movement kinematics (e.g., peak velocity, deceleration, movement adjustments) were evaluated. Differences between groups were apparent in quantity and quality of movement. Healthy subjects were stronger and faster than frail subjects, producing smoother movements with fewer adjustments. Strength appears to differentially affect healthy and frail samples and merits further exploration.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>LIST OF TABLES</th>
<th>v</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIST OF ILLUSTRATIONS</td>
<td>iv</td>
</tr>
</tbody>
</table>

Chapter

I. INTRODUCTION ...................................... 1
   - Definition of terms
   - Delimitations of study
   - Research hypotheses

II. REVIEW OF THE LITERATURE ....................... 6
   - Introduction
   - Models and theories of neural aging
   - Physiological changes
   - Psychomotor changes
   - Implications

III. METHODS .......................................... 23
   - Subjects
   - Instruments
   - Apparatus
   - Procedures
   - Design and Analysis

IV. RESULTS ........................................... 33
   - Subject characteristics and physical performance measures
   - Psychomotor performance measures
   - Correlational data

V. DISCUSSION ........................................ 42
   - Subject characteristics and physical performance measures
   - Psychomotor performance measures
   - Correlational data
   - Conclusions
   - Future directions
LIST OF TABLES

Table 1. Subject characteristics by group............. 34
Table 2. Kinematic characteristics of psychomotor performance by group............. 35
Table 3. Correlations between psychomotor performance measures and right grip strength.................. 40
Table 4. Correlations between physical performance measures and movement time.................. 41
LIST OF ILLUSTRATIONS

<table>
<thead>
<tr>
<th>Figure 1. Experimental design for healthy and frail groups</th>
<th>32</th>
</tr>
</thead>
</table>
CHAPTER I

INTRODUCTION

According to the Bureau of the Census (Spencer, 1989), by the year 2000, the general population will be older, with a median age of 36 years, compared to 29 years in 1975. Americans over the age of 65 will account for 35 million people in 2000, or approximately 13% of the population, in contrast with 8% in 1950. Almost 60% of those individuals over the age of 65 are female (Spencer, 1989). Aging may be specifically defined several ways, though it is generally understood to be an inevitable and gradual process. Although this process is universal, every individual experiences it uniquely (Fozard, 1981). Research findings indicate that performance declines occur as a part of the aging process, particularly in terms of slower response time to stimuli by older adults than younger individuals (Salthouse, 1985; Spirduso & MacRae, 1990; Welford, 1985). These performance declines may be due to central or peripheral factors, or more likely, some combination of factors. Central factors are those that involve the central nervous system (CNS). CNS slowdowns may be explained by slower processing of available information (Cerella, 1990; Welford, 1982). Peripheral factors include those involving muscles and muscle activation; older individuals may become
less able to direct the body to do what it needs to do. Rather than losing motoric capabilities, those abilities simply seem to slow in older adults (Baylor & Spirduso, 1988; Goggin & Stelmach, 1990). Physiological systems and processes change very little in terms of responses to stimuli, despite changes in the physiological make-up of muscles (less muscle mass and a higher proportion of slow-twitch (Type I) to fast-twitch (Type II) muscle fibers) which would seem to indicate a loss of capability (Larsson, Sjodin, & Karlsson, 1978). Aerobic exercise training seems to result in improvements in short-term cognitive functioning in older adults (Rikli & Edwards, 1991). With anaerobic exercise training, even frail elderly people make significant improvements in strength capabilities (Fiatarone, Marks, Ryan, Meredith, Lipsitz, & Evans, 1990).

In order to address age-related changes in motor performance, a more comprehensive understanding of those changes is necessary. Participation in regular aerobic exercise may postpone or reduce age-related declines in performance on psychomotor tasks (Baylor & Spirduso, 1988; Rikli & Edwards, 1991; Spirduso & MacRae, 1990; Spirduso, MacRae, MacRae, Prewitt, & Osborne, 1988). Tasks requiring rapid initiation and completion of movement (i.e., reaction time (RT) and movement time (MT)) appear to improve significantly after aerobic exercise training (Baylor &
Spirduso, 1988; Rikli & Edwards, 1991). While the value of this research is unquestionable, it does not advance understanding of anaerobic processes in movement and aging. Strength is a physiological, anaerobic factor which has received little attention in terms of its relation to movement control in elderly populations. Most studies of anaerobic components of exercise and movement have involved populations of males (Frontera, Marks, Ryan, Meredith, Lipsitz, & Evans, 1988; Larsson, Sjödin, & Karlsson, 1978; Kallman, Plato & Tobin, 1990); yet, a greater proportion of the over 65 population is female (Spencer, 1989).

The purpose of this study was to compare muscle strength and psychomotor performance measures in healthy and frail groups of elderly women utilizing movements which required various amounts of strength and ballistic action.

For the purpose of this study, the following definitions were used:

**Ballistic movement.** Brisk muscular contractions performed as fast as possible with no time for corrective feedback action (Desmedt & Godaux, 1977).

**Elderly; Older adults.** Individuals over 65 chronological years of age; terms used interchangeably.

**Frail.** Subjects living in congregate dwellings with low overall scores (an average score of 5 or less) on the four items of the functional assessment completed by all subjects (see Functional Assessment form in Appendix A).
Healthy. Subjects living independently in the community with high overall scores (an average score of 6 or 7) on the four items of the functional assessment completed by all subjects (see Functional Assessment form in Appendix A).

Movement Time (MT). The interval of time between the initiation of a response and completion of movement (Magill, 1993).

Reaction Time (RT). The interval of time between the onset of a signal (stimulus) and the initiation of a response (Magill, 1993).

Strength. Ability of muscle groups to exert maximal isometric force in a single voluntary effort (Knapik, Wright, Mawdsley, & Braun, 1983).

DELIMITATIONS:

1. Use of self-report of physical activity level and past medical history (see Subject Questionnaire in Appendix B).
2. Use of a convenient sample of elderly women in Denton, TX. This condition should be overcome through the use of the Digit Symbol Substitution Test (DSST) instrument, which provides age group norms to ensure a representative sample.
RESEARCH HYPOTHESES:

1. Differences in performance levels will occur on physical and psychomotor measures between healthy and frail subjects.

2. Subjects in the healthy group will demonstrate superior performance levels than subjects in the frail group (e.g., quicker MTs, more grip strength, higher scores on the functional assessment).

3. Muscle strength, represented by grip strength, is related with psychomotor measures, particularly those associated with quality of movement (e.g., deceleration, homing, movement adjustments).
CHAPTER II

REVIEW OF THE LITERATURE

The purpose of this study was to compare muscle strength and psychomotor performance measures in healthy and frail groups of elderly women utilizing movement which required various amounts of strength and ballistic action. This chapter is divided into 1) Introduction; 2) Models and Theories of Neural Aging; 3) Physiological Changes; 4) Psychomotor Changes; and 5) Implications.

Introduction

In 1988, 12.4% of the American population was over the age of 65 (Spencer, 1989). Females accounted for approximately 58% of those over the age of 65 in 1980 and 1988. The most rapidly growing population in the next decade will be individuals over the age of 85, increasing in number by about 30% totaling approximately 4.6 million by the year 2000 (Spencer, 1989). Understanding the intertwining mechanisms of aging, as demonstrated through physiological and psychomotor changes, will become especially important as a larger segment of the population experiences those changes.

Models and Theories of Neural Aging

Aging is a gradual process, but not a uniform one. That is, each individual experiences the aging process
uniquely. Woollacott (1989) describes two alternate models of aging, which are specific to the neural system, but may apply in a more general sense. One accepted model, General System Decline, proposes a linear decline in nervous system function with age, as the number of neurons in a specific area of the brain decreases below the threshold for normal functioning. A second model, System-Specific Decline, proposes instead a non-linear model of decline in neuron function, with declines occurring only when a specific event, such as disease occurs. Neither of these models has been adequately tested, particularly since subject pools have included individuals experiencing normal aging as well as those with some degree of pathology.

Two theories which explain the neural consequences of aging are Welford’s (1981, 1985) neural noise theory and Cerella’s (1990) neural net theory. Both theories address changes which most directly explain slower RTs of the older population in general. Both theories arise from an information processing model of the central nervous system (CNS). The primary functions of the CNS are integration of incoming stimuli, modification of stimuli as necessary, execution of motor movements, storage of information (memory), and generation of thoughts or ideas. An information-processing model interprets the neural workings of the brain as essentially computer-like. Input (sensory information) is required by the brain for processing into
output (thought, action). Both Welford and Cerella view age deficits as wrinkles in a sort of neural network. Psychomotor behaviors involve some information processing, thus these behaviors are at some level dependent on the integrity of the CNS. CNS integrity is known to decline with chronological age (Curcio, Buell & Coleman, 1982; Welford, 1982), so psychomotor behavior measures such as RT have often been used as age markers (Spirduso & MacRae, 1990).

Welford's (1981, 1985) theory is based on signal detection theory. That is, younger people have a greater ability to filter out extraneous noise from the environment. Fully functioning individuals are able to select relevant information from the environment and filter out the rest. In a functioning system, if a task calls for balance, vestibular and equilibrium information will be allowed through to aid in the completion of the task. Other information, not immediately useful, will be ignored or stored for later use. Welford explains that with age the filters become less finely tuned, allowing extra information in, or at least picking it up, which then has to be sorted through. It takes more time to pick up and filter information than to ignore it. This may explain why it takes longer for older adults to react to a stimulus—theyir systems require longer time to process the signals from noise (excess sensory information) coming in.
Cerella's (1990) neural net model proposes a system comprised of links (neurons) used to process information from input to output. As in any efficient system, the quickest path is a straight line. However, as the system ages, these links deteriorate. This situation demands that new links along a less efficient path be formed or that existing, nondirect links be utilized. These less direct pathways, as well as lack of activation of peripheral mechanisms (particularly muscles), account for increased processing time and result in slower RTs. Both theories are similar in attributing poorer functioning to deterioration of the CNS and subsequent increases in cycle time (the amount of time taken from input to output), though Welford might argue that Cerella's theory does not rule out breakdowns elsewhere in the system. Salthouse (1985) appreciates the views of both theories in terms of systemic breakdown and generalized slowing of the system. However, perhaps it is more likely that age-related changes are not limited to neural pathways, but include the entire physiological system. Changes in one area probably lead to corresponding changes in other parts of the system. Although Salthouse finds that peripheral factors contribute very little to the slowing with age phenomenon, it is unclear what constitutes "very little" or enough. Salthouse (1985) points out that explanations for age-related slowing exist in terms of both hardware and software differences in
systems. Hardware differences are comparable to Welford's (1981, 1985) neural noise hypothesis. That is, the processing unit (CNS) of a young person is functionally different from that of an older person. Software differences reflect inconsistencies in the quality of the control mechanisms utilized. That is, strategies used to complete an action are different for young and older adults.

**Physiological Changes**

A major problem in comparing the results among the available elderly research is the difference in the health of the subjects. Fozard (1981, p. 8) points out that "(e)ven with a constant environment, there are enormous individual differences in behavior and the way in which behavior is influenced by such biological processes as deossification of bones, decrease in the accommodative power of the eye, graying of the hair, and so on." Older adults may be relatively homogeneous compared to young adults in that older adults probably occupy fewer formal social, economic, occupational, and consumer roles. However, older adults are typically more heterogeneous than young adults in terms of physiological measures including blood pressure, glucose tolerance, and RT. Environmental changes that affect the aging process include "... changes in diet, smoking habits, educational and health care practices, air pollution, pension plan and mandatory retirement ages, and changes in leisure habits and sexual customs" (Fozard, 1981, p. 8).
As adults age, they are likely to lose much of the strength of youth (Astrand & Rodahl, 1986). Strength is the ability of a muscle group to exert maximal force in a single voluntary effort and assumes a general physiological capacity (Knapik et al., 1983). Evidence does exist for a generalized strength component (Hortobagyi, Katch & LaChance, 1989; Asmussen, Hansen & Lammert, 1965). In a study of three groups of males (M = 34.3 years, 54 years, and 66 years, respectively), Rich (1988) found that older subjects showed slower RTs and a decreased ability to recruit strength capabilities than younger subjects due to an age-related decline in peripheral mechanisms to respond to resisted action.

Males reach peak strength levels at approximately age 20, females reach peak strength two to three years earlier (Astrand & Rodahl, 1986). At age 65, muscle strength has decreased by 20-25% of that attained between the ages of 20 and 30 (Astrand & Rodahl, 1986). Strength decreases are especially apparent in the muscles of the legs and trunk. Decreases in muscle cross section area (CSA) seem to account for some strength decreases in elderly males (Overend, Cunningham, Kramer, Lefcoe, & Paterson, 1992). Indeed, strength decline seems to parallel muscle mass reduction. However, maximal strength per unit of CSA of skeletal muscle is approximately the same in males and females, regardless of age (Astrand & Rodahl, 1986). A decrease in muscle
fibers seems to be less important than the change in fiber type distribution. With age, a decrease in the percentage of Type II (fast-twitch) fibers occurs (Larsson, et al., 1978). This change may provide some explanation for increases in RT. However, other evidence exists which suggests that loss of muscle fibers may not be type-specific (Green, 1986).

A loss of muscle volume is perhaps due to reduced fiber size, particularly fast-twitch (Type II) fibers. This would result in a proportional increase in slow-twitch (Type I) fiber area. Another possibility is a reduction in the total number of fibers. One cause of such a reduction might be the loss of functioning motor neurons. Denervation of muscle fibers would eventually result in atrophy and gradual replacement of fiber area by connective tissue (Stamford, 1988). Another possibility is a loss of fast-twitch neurons rather than fast-twitch fibers. If there is a loss of fibers, the discrepancy might be explained between the retention of muscle endurance abilities and loss of strength, or more specifically, power potential. However, if fast-twitch neurons are lost prior to fiber loss, a strong physiological case could be made for Cerella's neural network theory, which emphasizes a decline in CNS functioning.

Muscular strength and muscular endurance decrease significantly with age (Clarke, Hunt, & Dotson, 1992).
However, the relationship between muscle function and age may not be quite that simple. Deficits associated with aging cannot be generalized to all sensory and motor systems, possibly because of differences in the sustained frequency of use with age (Meeuwsen, Tesi & Goggin, 1992). Bemben, Massey, Bemben, Misner, and Boileau (1991) found that patterns of decline in muscle function are independent. Loss of muscle function in the lower extremity generally occurs at an earlier age than that of the upper extremity. One explanation offered is the change in physical activity patterns that occurs with age. For example, the use of the hands is important at all ages, for fine motor skills such as writing. However, for most people, there is a decline in the need to maintain the ability to perform explosive gross motor activities such as jumping.

Bemben et al. (1991) did not find differences in lean body mass between age groups (ranging from 20 to 74 years of age) until 70 years, suggesting the potential to maintain muscle function. In a study of young (19 to 55 years) and elderly (74 to 90 years) male and female subjects, Phillips, Bruce, Newton and Woledge (1992) found that while older subjects were weaker than younger subjects, neural activation in the muscles for both groups was similar.

Grip strength measurement is used quite often in the physical assessment of older adults (Elko & Ostrow, 1992; Petrofsky, Burse & Lind, 1975; Kallman, Plato & Tobin,
A significant linear decrease in static grip strength occurs as a function of chronological age (19 to 65 years) in women (Petrofsky et al., 1975). Kallman et al. (1990) state that losses in muscle mass partially account for an age-related decline of grip strength in women, but suggest other factors, including progressive inactivity. Petrofsky et al. (1975) noted that though strength decreased in women, muscular endurance increased with age in the same group of 19 to 65 year-old women.

In a review of the literature pertaining to exercise and the elderly, Stamford (1988) discussed findings that males experience a decline of approximately 20% in grip strength between the ages of 20 and 65 years of age. Research findings for females indicate grip strength declines ranging from 2-20% for the same age groups. The difference in findings may be due to a smaller peak in muscle strength for females in part explained by less occupational use of the hands (Shephard, 1987). Petrofsky et al. (1975) found that males between the ages of 20 and 65 years who performed similar occupational duties experienced no significant decline in grip strength.

Stones and Kozma (1982) found that aging affected aerobic events more than anaerobic events. Yet strength, an anaerobic measure, clearly declines with age (Astrand & Rodahl, 1986; Stamford, 1988). Research on muscular strength in older populations is relatively rare, thus the
amount of muscular and neural plasticity available to the elderly through training is unclear, as are the training requirements for changes to occur (Spirduso & MacRae, 1990).

**Psychomotor Changes**

Age deficits are probably not attributable to one single mechanism or process (Stelmach & Worringham, 1985). Changes in one part of the system probably affect other parts. To what degree the system and processes change (hardware) compared with the control of the system and processes (software) and how the two may combine to result in completely different actions is not yet understood.

Lovelace and Aikens (1990) suggest that kinesthetic and motor control systems are relatively well-preserved in healthy older (55 to 85 years) adults. In a study by Rikli & Busch (1986), active and inactive young \( (M = 22.2 \text{ years of age}) \) and older \( (M = 68 \text{ years of age}) \) women were compared on measures of flexibility, grip strength, balance and RT. Overall mean scores for the young women were better than those of the older women and the active women scored better than inactive women. Larger differences existed between active and inactive groups than between age groups. Motor performance may be related more to physical activity level than age.

The motor behavior and development literature indicates that aging individuals can maintain their levels of
functioning on various motor tasks but take longer to complete those tasks (Goggin & Stelmach, 1990). Indeed, response slowing may simply be an outward indication of a generalized slowing pattern (Campbell, Borrie, & Spears, 1989; Ochs, Newberry, Lenhardt, & Harkins, 1985; Salthouse, 1985; Simoneau, Cavanagh, Ulbrecht, Leibowitz, & Tyrrell, 1991; Teasdale, Stelmach, & Breunig, 1991). A study of movement planning by Stelmach, Goggin, and Garcia-Colera (1986) found that older adults ($M = 69.6$ years) were able to utilize advance information to prepare for movements, but RT and MT were undoubtedly slower for adults in the older group than those in the two younger ($M = 20.6$ years and 44.3 years) groups. These findings support a generalized slowing hypothesis.

Much of the research completed on changing psychomotor abilities is based on the work of Fitts (1954). The trade-off between speed and accuracy was studied by Fitts (1954) by manipulating the difficulty of the task. The task index of difficulty (ID) is a combination of target width ($W$) and amplitude ($A$), or distance traveled. MT was found to increase linearly with increases in the task ID (Fitts, 1954). Fast aiming movements are made at the expense of reduced accuracy and accurate movements are made at the expense of reduced speed (Fitts, 1954). In addition, aiming movements have an initial ballistic phase (speed) followed by a feedback phase (accuracy) (Crossman & Goodeve, 1983;
Woodworth, 1899). Ballistic forces are produced through brisk muscular contractions executed as quickly as possible and for which there is no time for feedback from neuromuscular mechanisms (Craik, 1947; Desmedt & Godaux, 1977).

Supporting studies with older adults involving aiming movements to targets found that two kinematic processes are utilized by older subjects. The first was an initial fast movement to cover distance quickly, and the second was a slower movement to "home in" on the target and reduce accuracy errors (Crossman & Goodeve, 1983; Warabi, Noda, & Kato, 1986; Welford, Norris, & Shock, 1969). Older adults tend to emphasize accuracy and perform slight adjustments to their movements in order to improve accuracy (Rabbitt, 1982). Increased task accuracy requirements may require more control and precision of movements, indicated by a longer deceleration phase of movement (Goggin & Meeuwsen, 1992; Marteniuk, MacKenzie, Jeannerod, Athenes, & Dugas, 1987). Examination of the kinematic characteristics of movement, including velocity and acceleration, may be useful in understanding control processes utilized in movement execution (Annett, 1988).

While aging appears to affect simple RT only slightly, that effect becomes more pronounced as movement complexity is increased (Gottsdanker, 1982). Light and Spirduso (1990) found that older female subjects were more sensitive to
small changes of movement complexity in a switch-pressing task than their younger counterparts. Changes in force production requirements may or may not increase movement complexity, possibly accounting for slowed RTs and MTs in young adult males (Anson, 1989; Baba & Marteniuk, 1983). Such changes in force production requirements may have a more pronounced effect on older subjects.

Goggin, Jackson, and Meyer (1993) conducted a study to determine the relationship between strength and motor performance in elderly women (65 or more years of age). Subjects \((N = 20; \text{M age} = 73.1 \text{ years})\) were measured on grip strength, upper and lower body strength as well as a variety of psychomotor measures, which were recorded through the use of a stylus and digitizing tablet. Subjects used the stylus to perform simple aiming movements to targets projected onto the digitizing tablet. A variety of information including RT, MT, and qualitative data was gathered. Psychomotor movement information was correlated with strength data during the analysis phase of the study. An attempt was made to consider "strong" and "weak" groups in this study, by splitting the group according to grip strength. However, few differences were found. Findings indicated that stronger subjects had slower MTs and achieved less peak velocity but produced greater deceleration. These findings suggest that strength may be an indicator of superior control in the completion of simple aiming movements. The
lack of clear effects in "strong" versus "weak" groups may have been due to the homogeneity of that subject population. The subjects in that investigation were independent community dwellers who exercised vigorously on a regular basis and experienced no serious health problems.

Implications

O'Brien and Vertinsky (1991) report findings that normal aging for one sample of elderly women tends to follow this profile: 75% are physically limited in daily activity; 60% of women over age 65 have been screened out of random public physical fitness testing for reasons of health risk, and 46% are institutionalized by age 85. Spirduso, et al. (1988) suggest that aerobic exercise may delay the loss of RT speed associated with age. Although the number of muscle fibers and motor units decrease over the years, the physiological mechanisms themselves do not change that much over time. In older women, regular aerobic exercise is an important factor influencing the speed of reactions to simple and choice stimuli, and in the accompanying cognitive time, muscle contractile time, and speed of movement (MT) following reaction responses (Baylor & Spirduso, 1988; Rikli & Edwards, 1991). Age is not necessarily an appropriate guide to exercise prescription, mainly because age-related declines in aerobic power are highly individual; the decline in aerobic power is not linear over time (Cunningham & Patterson, 1990; Drinkwater, 1988). In addition, apparent
declines in aerobic fitness may be more an artifact of increased body fat than a factor of age (Plowman, Drinkwater & Horvath, 1979). Clear indications exist that aerobic forms of exercise are beneficial among all age groups.

Unfortunately, anaerobic capacities of the elderly remain unknown. Stamford (1988) found that the capacity to respond to physical training is independent of one's physical activity history (i.e., it is never too late to start). According to Hindmarsh & Estes (1989), a lack of basic strength is blamed for the majority of falls experienced by one-third of all adults over 65. However, the medical model, in which an outcome, such as a fall, is related to a single etiologic factor, is seldom applicable to elderly individuals. A threshold model, combining a number of factors to limit the individual's overall functional status, is more applicable in most cases. Falls are usually the result of the interaction of many factors, including environment, previous experience, judgment, vision, hearing, proprioception, strength, neurologic and cardiovascular status, polypharmacy (taking more than one prescription drug), and others (Hindmarsh & Estes, 1989). Any single added problem, which would be relatively minor under other circumstances, can disturb the balance and lead to one or a series of falls. A commitment to an active life-style, even if it does not extend life, plays an important role in maintaining one's mobility and physical
independence (O'Brien & Vertinsky, 1991). These abilities are promoted by other long-term benefits of exercise such as improved joint flexibility, muscular strength and muscle endurance, increased muscle mass, the retardation of osteoporosis, and increased bone mineralization (O'Brien & Vertinsky, 1991).

Much research remains to be done concerning the attributes of muscular strength and endurance in the elderly. Spirduso & MacRae (1990, p.196) state "...it would be extremely useful to know the contribution that different levels of muscular strength and power might make toward the prevention of injuries, accidents, and fatalities in the very old." Further, "research regarding the characteristics of the exercise-psychomotor-mental relationships and the mechanisms by which exercise contributes to these relationships should have a high priority" (Spirduso & MacRae, 1990, p. 197). Fiatarone et al. (1990) found that frail nursing home residents could complete an eight-week high-intensity resistance training program and make significant strength gains. The average age of the subjects (N = 10) was 90 years. The subjects included six female and four male residents. Average strength gains were 174% over baseline measures. The results of this study clearly indicate that resistance training is feasible with frail elderly populations and may result in significant strength gains.
The present investigation examines differences in strength and psychomotor performance between healthy and frail populations of elderly females. Although it seems clear that aerobic exercise regimens have great impact upon the quality of life of elderly individuals, little is known about the relationship between muscle strength and psychomotor measures.
CHAPTER III

METHODS

The purpose of this study was to compare muscle strength and psychomotor performance measures in healthy and frail groups of elderly women utilizing movements which required various amounts of strength and ballistic action. This chapter is divided into 1) Subjects; 2) Instruments; 3) Apparatus; 4) Procedures; and 5) Design and Analysis.

Subjects

The subjects in this study were 41 right-hand dominant Caucasian females ranging in age from 66-92 years. Subjects were divided into healthy and frail groups. Two subjects, one from each group, were unable to complete all tasks. Data from the remaining 39 subjects was used for all analyses. The healthy group consisted of 18 subjects ranging in age from 66-92 years (M = 75.74 years, SD = 6.71) living in independent community dwellings. The frail group consisted of 21 subjects ranging in age from 71-92 years (M = 80.45 years, SD = 6.37) living in congregate living environments. An ANOVA revealed no significant difference in age between the groups. A self-report of physical health and activity level was provided by each subject (see Appendix B). Eighty-three percent (83%) of healthy subjects reported good or excellent health. Eighty-one percent (81%)
of frail subjects reported fair or good health. Healthy subjects were prescribed an average of 1.88 medications, while frail subjects averaged 2.52 prescription medications. Sixty-four percent (64%) of all subjects (12 of 18 (67%) healthy subjects and 13 of 21 (62%) frail subjects) reported regular exercise participation, though further description of exercise programs by subjects indicated a wide range in the intensity of exercise performed. For example, some subjects performed calisthenics each morning for approximately 15 minutes, others walked approximately one mile at a frequency of three to five times per week; other subjects taught exercise classes; still others took part in rehabilitative regimens of stretching and flexibility exercises. The discrepancies evident between these exercise programs, in terms of frequency and intensity, do not allow comparisons to be made between said programs.

**Instruments**

The Older Americans Research and Service Center Instrument (OARS), developed at Duke University (1978) is a multidimensional instrument for assessing functional status in the non-institutionalized elderly. Information regarding functional activity in five domains (social resources, economic resources, mental health, physical health, and activities of daily living (ADL)) is yielded by administration of the OARS. From the responses to the questions in each domain, functional status is assessed in
each dimension along a six-point performance rating scale where 1 = excellent functioning and 6 = totally impaired. The six-point scale can be collapsed to a dichotomous scale where individuals rated 1-3 are considered to be functioning adequately and those 4-6 are considered to be impaired for that dimension. Test-retest reliability (3-6 week interval) on the physical health and ADL scales of the OARS is indicated by a correlation coefficient of .82 (Kane & Kane, 1981). The physical health scale was utilized in the present investigation. The physical health scale assesses the presence of physical disorders and participation in physical activities. Only the self-report questions (no observer data) were utilized (see Appendix D). Raw scores rather than OARS scaled scores were used for physical functioning. Results of the OARS reveal lower scores for healthy subjects (M = 17.05, SD = 7.5) than frail subjects (M = 26.05, SD = 14.91), indicating higher levels of physical functioning for healthy subjects. Only two subjects (both in the frail group) required some assistance with one to three ADLs. According to the performance rating scale of the OARS for ADLs, all subjects in the present investigation received a rating of one to three, indicating adequate functioning on activities of daily living. OARS scores are reported with the data analysis (see Table 1).

The Digit Symbol Substitution Test (DSST), a subtest of the Wechsler Adult Intelligence Scale (WAIS) and the WAIS-
Revised (Wechsler, 1985), involves stimulus identification, encoding, and short-term memory. Subjects are required to associate specific symbols with each of the numbers 1-9 and to copy as many of them as possible into designated spaces below the corresponding numbers. The score is the number of correct responses completed within a 90-second time limit. Practice on seven demonstration frames occurs prior to testing. The DSST may provide the best available index for psychomotor age (Salthouse, 1985). The test-retest (one- to seven-week interval) correlation has been found to be above .80, which indicates a high degree of reliability. The purpose of the DSST is to determine if a subject's psychomotor speed corresponds to the norms for subjects in comparable age group populations (Salthouse, 1985). DSST norms have been determined for adults up to 75 years of age. A significant between-group difference, $F(1,38) = 11.16$, $p < .003$, was found on DSST scores, with scores for the healthy group ($M = 43.17, SD = 11.92$) higher than those for the frail group ($M = 30.90, SD = 10.98$).

**Apparatus**

The apparatus used in this experiment included a JAMAR hand dynamometer, a Houston Instruments Hi-Pad Plus Digitizing Tablet with an electronic stylus with which the subjects produced aiming movements, and an IBM-compatible personal computer. The digitizing tablet recorded horizontal and vertical (X,Y) coordinates, accurate to 0.1
mm. Templates containing combinations of the starting position and target squares were placed underneath a clear sheet of plastic which covered the surface of the digitizing tablet (see example in Appendix D). Two movement conditions, with amplitudes of 15 cm and 30 cm (measured from the center of the starting square to the center of the target square) were used (based on Fitt's Law, 1954). The combination of short distance (15 cm) and 2.0 cm target width constituted the "Easy" target condition and the combination of long distance (30 cm) and 1.0 cm target width provided the "Hard" target condition. In addition, two resistance conditions, "Weight" (1.1 lbs) and "No Weight", were utilized. The resistance was provided by attaching a wrist weight to the dominant wrist with an adjustable fastener. Thus, four different movement conditions were utilized in this study, with 12 trials conducted in each condition (Easy/No Weight, Easy/Weight, Hard/No Weight, Hard/Weight), for a total of 48 trials per subject.

**Procedures**

All subjects were tested on site, either at the senior center or within the congregate dwelling. All subjects signed a notice of informed consent approved by the Institutional Review Board of the University of North Texas (see Appendix C). Administration of the DSST occurred prior to strength and motor performance evaluation. For the DSST, the subject was seated at a table or desk with the
instrument and pen or pencil. All procedures were explained and demonstrated prior to subjects' testing.

The functional assessment (Tideiksaar, 1989) involved the evaluation of performance on four movement abilities (see Appendix A). Tasks performed were: 1) sitting down and rising from a chair; 2) walking a short distance; 3) standing and reaching above the head; and 4) bending down to touch the toes. The assessment was made through the use of a Likert-type scale, with scores ranging from 1 (poor) to 7 (excellent). Evaluation included quality of movement concerns. For example, did the subject require a prop to rise from or sit down on the chair; examination of stride length, height of step, and arm swing on the walking task. Two other tasks (climb/descend stairs, lie prone on the ground and get up unassisted) are included on the Tideiksaar assessment, however, due to environmental constraints (e.g., lack of stairs, lack of floor covering), not all subjects completed those tasks.

The strength testing device utilized was the JAMAR hand dynamometer to measure grip strength (lbs). The standard procedure recommended by the manufacturer was followed, during which subjects sat comfortably with the shoulder adducted and neutrally rotated. The elbow was flexed to 90 degrees, with the forearm and wrist in anatomically neutral positions. Three grip strength measures were collected on each hand and the average reading obtained for each hand was
used for statistical analysis. Subjects were allowed to rest for 3 minutes between each grip strength measure. The OARS physical health section questions were completed during strength testing 3-minute rest periods.

The motor performance measures utilized in this study were reaction time (RT), movement time (MT), and movement accuracy, all of which were measured on the Houston Instruments Digitizing Tablet with a stylus and the personal computer. Movement accuracy was assessed by analysis of the qualitative features of the movements performed by the subjects, including peak velocity (PV), time to peak velocity (TPV), peak acceleration (PA), time to peak acceleration (TPA), peak deceleration (PD), time to peak deceleration (TPD), homing, impulse, and movement adjustments. The psychomotor measures were performed with the subject seated at a table or desk upon which the apparatus was centered. The stylus was held in the subject's dominant hand. All measures were obtained by the production of simple, aiming movements to the targets with a stylus. Movements were cued by computer-generated tones, which signalled "Ready", "Start", and "Stop" conditions. The stylus remained in contact with the tablet until the "Stop" tone sounded.

An IBM-compatible personal computer controlled the presentation of the stimuli and the recording and storage of all responses. Each subject received 24 practice trials to
become familiar with the tasks. Subjects practiced six trials in each of the four conditions (2 movement conditions x 2 resistance conditions) which were presented in a counterbalanced order across subjects. Data analyses included 12 test trials for each of the four conditions, resulting in a total of 48 analyzed trials.

Trials in which an error occurred were repeated. Errors included (1) anticipation errors (RT less than 100 ms), (2) movements in which subjects did not land in the target square at the end of the movement, and (3) lifting or moving the stylus from the target square prior to the end of the sampling period ("Stop" tone). The subjects did not receive any specific feedback about their performance, but were reminded to keep on task as necessary.

The task was a simple RT task, because the subject knew in advance the response to be produced. A typical trial began by the subject placing the tip of the stylus in the starting square. Subsequently, computer-generated tones were used for the warning signal ("Ready"), signal to begin movement ("Go"), and the signal that indicated the end of the sampling period ("Stop"). The warning signal ("Ready") was 250 ms long and was followed by a randomly altered foreperiod of 250, 500 or 750 ms to prevent subjects from anticipating the onset of the stimulus signal. The stimulus signal ("Go") was 500 ms long, and indicated the onset of movement. Subjects were instructed to move "as quickly and
as accurately as possible" to generate ballistic motion. The third tone ("Stop") indicated the end of the 2.0 second sampling period. The subjects kept the stylus down and in the target square until the third tone sounded. They were then allowed to lift the stylus and return to the starting square in preparation for the next trial.

Design and Analysis

The 2 x 2 x 2 x 12 (Group x Movement Condition x Resistance Condition x Trial) experimental design is depicted in Figure 1. Movement and resistance conditions were counterbalanced across all subjects. That is, subjects were randomly assigned a condition order so that some subjects started in easy and hard, weighted and unweighted conditions. All subjects completed 12 trials in each condition.

Separate analyses were conducted on psychomotor and physical performance measures. A 2 x 2 x 2 x 12 (Group x Movement Condition x Resistance Condition x Trial) ANOVA with repeated measures on movement and resistance factors was utilized to examine psychomotor variables. No trials effect was found, and a 2 x 2 x 2 (Group x Movement Condition x Resistance Condition) ANOVA with repeated measures on the last two factors was used to examine physical performance measures. Descriptive statistics including means and standard deviations were computed for all measured variables. The dependent measures in this
experiment included RT, MT, peak velocity (PV), time to peak velocity (TPV), peak acceleration (PA), time to peak acceleration (TPA), peak deceleration (PD), time to peak deceleration (TPD), deceleration (DEC), homing (HOM), impulse, movement adjustments (ADJ), grip strength, OARS score, and functional assessment scores.

The Bonferroni technique was utilized on psychomotor and functional measures to adjust experimentwise alpha. An alpha level of .05 was divided by the number of comparisons to be made on dependent variables. The technique yielded an alpha level of .00625 for psychomotor measures. Dependent measures analyzed were MT, PV, TPV, PA, TPA, DEC, HOM, and ADJ. An alpha level of .00714 was used for physical assessment measures. Dependent measures analyzed were RGS, LGS, OARS, SIT, WALK, STAND, and BEND. Pearson product moment correlations were calculated for all variables.

<table>
<thead>
<tr>
<th>Resistance Condition</th>
<th>Easy</th>
<th>Hard</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Weight</td>
<td>12 trials</td>
<td>12 trials</td>
</tr>
<tr>
<td>Weight</td>
<td>12 trials</td>
<td>12 trials</td>
</tr>
</tbody>
</table>

Figure 1. Experimental design for healthy and frail groups.
CHAPTER IV

RESULTS

The purpose of this study was to compare muscle strength and psychomotor performance measures in healthy and frail groups of elderly women utilizing movements which required various amounts of strength and ballistic action. This chapter is divided into 1) Subject Characteristics and Physical Performance Measures; 2) Psychomotor Performance Measures; and 3) Correlational Data.

Subject Characteristics and Physical Performance Measures

Means and standard deviations for subject characteristics are presented in Table 1. A one-way ANOVA revealed significant main effects for group on DSST scores, \( F(1,38) = 8.562, p < .01 \), right grip strength, \( F(1,38) = 9.25, p < .005 \), and the functional assessment scores (sit down/rise from chair, \( F(1,38) = 19.22, p < .0001 \), walk in a straight line, \( F(1,38) = 17.47, p < .0001 \), stand on toes and reach overhead, \( F(1,38) = 64.30, p < .0001 \), and bend down and touch toes, \( F(1,38) = 58.93, p < .0001 \)). These findings indicate higher levels of performance for healthy subjects than for frail subjects.

Education level values (see Table 1) indicate the number of years of schooling received. No significant between-group differences were found for education levels.
Table 1

Subject Characteristics by Group (N = 39)

<table>
<thead>
<tr>
<th></th>
<th>Healthy M(SD)</th>
<th>Frail M(SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (Years)</td>
<td>75.33 (6.71)</td>
<td>80.57 (6.37)</td>
</tr>
<tr>
<td>DSST</td>
<td>42.21 (12.31)</td>
<td>31.20 (11.18)</td>
</tr>
<tr>
<td>OARS</td>
<td>17.05 (7.50)</td>
<td>26.05 (14.91)</td>
</tr>
<tr>
<td>Right Grip Strength (Lbs)</td>
<td>53.37 (12.60)</td>
<td>44.15 (9.25)</td>
</tr>
<tr>
<td>Left Grip Strength (Lbs)</td>
<td>46.95 (12.18)</td>
<td>39.45 (10.30)</td>
</tr>
<tr>
<td>Functional Assessment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(average overall score)</td>
<td>6.17 (1.01)</td>
<td>3.85 (.94)</td>
</tr>
<tr>
<td>Sit</td>
<td>6.05 (1.12)</td>
<td>4.50 (1.15)</td>
</tr>
<tr>
<td>Walk</td>
<td>6.05 (1.22)</td>
<td>4.40 (1.50)</td>
</tr>
<tr>
<td>Stand</td>
<td>5.94 (1.13)</td>
<td>3.35 (1.04)</td>
</tr>
<tr>
<td>Bend</td>
<td>6.16 (1.39)</td>
<td>3.10 (1.45)</td>
</tr>
<tr>
<td>Education Level (from OARS assessment)</td>
<td>6.26 (1.63)</td>
<td>5.40 (1.85)</td>
</tr>
</tbody>
</table>

Note: Education Level is as follows: 1 = 0-4 years of schooling; 2 = 5-8 years of schooling; 3 = high school incomplete; 4 = high school completed; 5 = post high school, business or trade school; 6 = 1-3 years of college; 7 = 4 years college completed; 8 = post graduate college; - = not answered.

Psychomotor Performance Measures

Means and standard deviations for psychomotor variables are presented in Table 2. Significant main effects occurred for group, \( F (1,1772) = 26.33, \ p < .0001 \), and movement condition (hard or easy), \( F (1,1772) = 16.93, \ p < .0001 \), on
Table 2

Kinematic Characteristics of Psychomotor Performance by Group

<table>
<thead>
<tr>
<th></th>
<th>Healthy</th>
<th>Frail</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M(SD)</td>
<td>M(SD)</td>
</tr>
<tr>
<td>RT (ms)</td>
<td>550 (290)</td>
<td>630 (310)</td>
</tr>
<tr>
<td>MT (ms)</td>
<td>500 (250)</td>
<td>680 (240)</td>
</tr>
<tr>
<td>PV (cm/sec)</td>
<td>108.16 (46.4)</td>
<td>74.6 (28.6)</td>
</tr>
<tr>
<td>TPV (ms)</td>
<td>210 (110)</td>
<td>310 (130)</td>
</tr>
<tr>
<td>PA (cm/sec²)</td>
<td>1028.93 (1091.58)</td>
<td>482.32 (394.73)</td>
</tr>
<tr>
<td>TPA (ms)</td>
<td>100 (120)</td>
<td>140 (110)</td>
</tr>
<tr>
<td>PD (cm/sec²)</td>
<td>-943.14 (782.0)</td>
<td>-536.02 (346.0)</td>
</tr>
<tr>
<td>TPD (ms)</td>
<td>340 (200)</td>
<td>500 (210)</td>
</tr>
<tr>
<td>DEC (ms)</td>
<td>290 (210)</td>
<td>380 (220)</td>
</tr>
<tr>
<td>HOM (ms)</td>
<td>160 (170)</td>
<td>180 (170)</td>
</tr>
<tr>
<td>ADJ</td>
<td>2.59 (1.6)</td>
<td>3.33 (1.7)</td>
</tr>
<tr>
<td>IMPULSE</td>
<td>108.40 (46.85)</td>
<td>74.68 (28.83)</td>
</tr>
</tbody>
</table>

Note: ADJ indicates the number of movement adjustments made by subjects across conditions. IMPULSE is the product of acceleration (a) multiplied by time (t).

RTs, indicating quicker reaction times for healthy subjects than for frail subjects and quicker reaction times for all subjects under easy conditions than for all subjects under hard conditions.

The MT analysis revealed significant main effects for group, $\overline{F}(1,1772) = 409.99$, $p < .0001$, and movement condition, $\overline{F}(1,1772) = 143.58$, $p < .0001$, indicating that frail subjects were significantly slower than healthy
subjects. Longer MTs in hard conditions for all subjects occurred as a result of the greater distance traveled and smaller target size, in support of Fitts‘ (1954) findings. There were no significant interactions between group and movement condition or group and resistance on either RT or MT measures. The present investigation found no significant interactions between movement and resistance conditions except those that occurred on acceleration displacement and y displacement variables. Significant interactions between group and movement condition, \( F(1,1772) = 35.15, p < .0001 \), occurred for group on acceleration displacement. A three-way interaction between group, movement condition, and resistance, \( F(1,1772) = 6.93, p = .009 \), also appeared in the acceleration displacement measure and approached significance. The y displacement variable indicates the amount of trajectory a subject utilizes in completing a movement. A significant interaction between group and movement condition, \( F(1,1772) = 11.42, p < .001 \), also occurred for group on y displacement. A three-way interaction between group, movement condition, and resistance appeared on the y displacement variable and approached significance, \( F(1,1772) = 6.42, p = .011 \). Frail subjects utilized less trajectory than healthy subjects in easy conditions, and more trajectory than healthy subjects in hard conditions. These interactions provide indications that the movements completed by frail subjects were
qualitatively different than the movements completed by healthy subjects.

An analysis of peak velocity data indicated significant main effects for group, \( F(1,1772) = 608.28, p < .0001 \), movement condition, \( F(1,1772) = 499.31, p < .0001 \), and resistance condition, \( F(1,1772) = 27.73, p < .0001 \). A significant two-way interaction between group and movement condition \( F(1,1772) = 12.13, p < .001 \), occurred on peak velocity. Healthy subjects showed greater peak velocity in their movements than did frail subjects. Subjects experienced lower peak velocities in easy conditions than in hard conditions and in weighted conditions than unweighted conditions. Significant main effects for group, \( F(1,1772) = 540.46, p < .0001 \), and movement condition, \( F(1,1772) = 111.18, p < .0001 \), were present on time to peak velocity. Frail subjects took longer to reach peak velocity than did healthy subjects and the time for peak velocity for all subjects in hard conditions was longer. The data for peak acceleration and peak deceleration, are highly correlated \( (r = .94 \text{ and } r = -.93, \text{ respectively, } p < .0001) \) with peak velocity and will not be discussed further. Time to peak acceleration and time to peak deceleration are similarly correlated \( (r = .91 \text{ and } r = .96, \text{ respectively, } p < .0001) \) with time to peak velocity and will not be discussed.

Significant main effects for group, \( F(1,1772) = 146.59, p < .0001 \), and movement condition, \( F(1,1772) = \)
48.93, \( p < .0001 \) occurred in the deceleration phase of movement. Frail subjects spent more time decelerating than did healthy subjects. All subjects spent more time decelerating in hard conditions than in easy conditions. These findings support the conclusions of Goggin and Meeuwsen (1992) that greater deceleration time indicates increased demand on movement control and precision. Homing occurs after the point of peak deceleration as the subject precisely adjusts movement so that the stylus will land in the target at the end of the movement. A main effect for group, \( F(1, 1772) = 6.14, p < .014 \), occurred on homing, approaching significance. Frail subjects required more time to "home in" on the target than did healthy subjects. No significant effects were found between groups for the percentage of movement time spent decelerating.

A movement adjustment was identified by computer algorithm when the subject's acceleration changed. A normal acceleration profile with no movement adjustments would have only two substantial changes, one for peak acceleration and one for peak deceleration. Any changes greater than two were considered to be movement adjustments (Goggin & Meeuwsen, 1992). Typical acceleration profiles for healthy and frail subjects may be seen in Appendix E. A significant main effect for group, \( F(1, 1967) = 95.76, p < .0001 \), occurred on movement adjustments. Movement adjustments made after peak deceleration, but prior to the end of the
movement may provide an indication of movement control. Frail subjects made more movement adjustments than healthy subjects, possibly indicating less control or less certainty in the movement endpoint.

An analysis of the impulse, or the integrated area under the acceleration curve, was conducted to determine any group differences. The areas of positive and negative acceleration were integrated and summed to provide a single score. Positive and negative acceleration (or deceleration) are dependent on the amount of force produced by the muscles. The sum of both positive and negative acceleration reflects muscle activation during the execution of the movement (Goggin & Meeuwesen, 1992). This analysis revealed a significant group effect $F(1, 1866) = 450.20, p < .0001$. Healthy subjects produced a greater total impulse ($m = 111.25, SD = 27.05$) than did frail subjects ($m = 73.60, SD = 19.47$). The effect for movement condition was also significant, $F(1, 1866) = 173.72, p < .0001$, indicating greater total impulse or muscle activation during longer movements.

**Correlational Data**

Significant correlational data for psychomotor and functional performance measures are displayed in Tables 3 and 4. Overall, high correlations exist between psychomotor and physical performance measures. Of particular interest are the significant correlations between the psychomotor
variable MT and physical functioning measures. MT was significantly correlated with grip strength in both hands. As grip strength increased, MT decreased. A significant correlation was also found between MT and one of the items of the functional assessment, standing on toes and reaching overhead. Statistical significance was approached on the correlation between MT and the functional assessment item, bending down to touch toes.

Table 3

Correlations between Psychomotor Performance Measures and Right Grip Strength (N = 39)

<table>
<thead>
<tr>
<th>Psychomotor Performance Measure</th>
<th>Right Grip Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Movement time</td>
<td>-.48 **</td>
</tr>
<tr>
<td>Peak velocity</td>
<td>.42 *</td>
</tr>
<tr>
<td>Time to peak velocity</td>
<td>-.39 *</td>
</tr>
<tr>
<td>Deceleration</td>
<td>-.45 *</td>
</tr>
<tr>
<td>Movement Adjustments</td>
<td>-.27</td>
</tr>
<tr>
<td>Homing</td>
<td>-.35</td>
</tr>
</tbody>
</table>

* p < .01
** p < .001
Table 4

Correlations between Physical Performance Measures and Movement Time (N = 39)

<table>
<thead>
<tr>
<th>Physical Performance Measure</th>
<th>Movement Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right Grip Strength</td>
<td>-.48 **</td>
</tr>
<tr>
<td>Left Grip Strength</td>
<td>-.40 *</td>
</tr>
<tr>
<td>Sit</td>
<td>-.30</td>
</tr>
<tr>
<td>Walk</td>
<td>-.29</td>
</tr>
<tr>
<td>Stand</td>
<td>-.48 **</td>
</tr>
<tr>
<td>Bend</td>
<td>-.36</td>
</tr>
</tbody>
</table>

* $p < .01$

** $p < .001$
CHAPTER V

DISCUSSION

The purpose of this study was to compare muscle strength and psychomotor performance measures in healthy and frail groups of elderly women utilizing movements which required various amounts of strength and ballistic action. This chapter is divided into: 1) Subject Characteristics and Physical Performance Measures; 2) Psychomotor Performance Measures; 3) Correlational Data; 4) Conclusions; and 5) Future Directions.

Subject Characteristics and Physical Performance Measures

Frailty is clinically defined as the inability to function independently in mental, social, emotional, or physical capacities (Kane & Kane, 1981). Fiatarone et al. (1990) utilized frail subjects, clinically defined through methods of patient classification. Clinical methods of patient classification include evaluation on several factors, including physical functioning (ADL and Instrumental ADL), cognitive functioning, affective functioning, social functioning, social support network, economic resources, formal and informal services received, and family well-being (Kane & Kane, 1981). Such a methodology is well-suited to institutionalized populations. However, physical performance measures are not utilized on
clinical populations and clinical methodologies are inappropriate in healthy populations.

Guralnik, et al. (1989) argue that the use of performance measures of physical functioning, in addition to self-report, provides valuable information to geriatric health care providers and researchers alike. In the present investigation, physical performance measures of grip strength and functional assessment items supplemented the subjects' self-report of physical functioning.

The results of this investigation indicate higher performance levels for healthy than for frail subjects on such tasks as grip strength, MT, and basic functional movement abilities. Significant between group differences were found on DSST scores, yet no significant age differences were found between groups in this study, although the frail group was somewhat older chronologically than the healthy group. Correlations between age and DSST scores were significant for the healthy group ($r = -.56, p = .008$), but not for the frail group ($r = -.013, p = .48$). This finding is somewhat anomalous. Ample variability existed across healthy and frail groups, so the lack of a significant correlation can not be explained by a statistically homogenous frail group. Differences in frailty do not match age changes as reflected by DSST norms. DSST norms have been calculated for individuals up to age 75, yet both groups in the present investigation had average
ages greater than 75 years. These findings suggest that DSST scores, traditionally considered to be more sensitive to age differences than other intelligence measures (Salthouse, 1985), may actually be sensitive to differences in functional ability. Frailty may express itself more upon those individuals who are less able to compensate for changes in functional ability than are healthy individuals.

Although subjects were questioned about physical activity level, that information was not analyzed, due to a lack of specific information. A majority of all subjects reported regular exercise participation. However, the same health and fitness benefits are not available through all "exercise" programs. Those engaging in routine bouts of vigorous exercise (brisk walking, jogging, swimming) receive greater cardiovascular benefits than those participating in milder forms of exertion.

The findings of the present investigation would seem to support system-specific decline concepts in physiological aging. These results support those of Meeuwsen, et al. (1992) that differences in frequency of use of sensory and motor systems disallow generalized age-related deficits in movement. Bemben et al. (1991) also found independent patterns of muscle decline, possibly due to changes in physical activity habits. The fact that two functionally different groups in the present investigation were not significantly different in age reflects that changes in
physical functioning are not due to age in and of itself. Subjects in the present investigation were evaluated on all measures within their own communities rather than a laboratory setting. Laboratory investigations on similar tasks may be able to more specifically measure strength, by utilizing more than one evaluation of muscular strength.

**Psychomotor Performance Measures**

Most research on psychomotor performance measures has involved comparisons between the performances of young and elderly subjects (Goggin & Stelmach, 1990; Gottsdanker, 1982; Light & Spirduso, 1990; Welford, Norris, & Shock, 1969). This research has indicated that elderly subjects move more slowly than young subjects. Comparisons between groups of elderly subjects have found that healthier adults have faster reaction times than less healthy adults (Abrahams & Birren, 1978; Light, 1978). The findings of the present investigation reflect that healthier elderly women display faster MTs on simple aiming movements than frail elderly women. Higher levels of physical functioning may affect psychomotor abilities.

The variability of motor performance increases with age (Salthouse, 1985) and may be due to physiological consequences of aging, declines in physical activity levels, decreases in motivation, changing performance expectations, the occurrence of disease, or some combination of those changes (Spirduso & MacRae, 1990). Though variability was
not specifically examined in this investigation, the
differences between movement patterns of healthy subjects
and frail subjects involve much more than simply speed of
movement. It may be more useful for studies involving
elderly populations to focus on movement quality issues,
(e.g., homing, deceleration), than simply RT and MT.
Significant interactions between movement and resistance
conditions and acceleration and $y$ displacement indicate
differences in movement execution between groups. Frail
subjects covered less distance during the acceleration phase
of movement and consequently, more distance in the
deceleration phase of movement than did healthy subjects in
easy movement conditions. In hard movement conditions,
frail subjects covered more distance in acceleration than
did healthy subjects. In terms of $y$ displacement, movements
made by frail subjects utilized less trajectory than those
made by healthy subjects. Acceleration profiles (see
Appendix E) provide clear illustrations that movement
quality was visibly different for frail and healthy subjects
in the present investigation. Healthy subjects produced
faster and smoother movement curves, relatively equal in
terms of time spent accelerating and decelerating. Frail
subjects, on the other hand, produced slower, much more
variable, and less smooth movements. Two movement
adjustments, one for peak acceleration and one for peak
deceleration, are features of normal acceleration profiles.
The number of movement adjustments made by frail subjects \((m = 3.33)\) was greater than that for healthy subjects \((m = 2.59)\). Such adjustments may provide more useful information about movement patterns in the elderly than measures such as RT and MT. Movement adjustments are reflective of subjects' concerns about accurately moving to a target. The greater number of adjustments produced by frail subjects indicates an uncertainty in the ability to complete the specified movement successfully, uncertainty that the system will perform as required.

The qualitative differences which exist within the movements of the community-dwelling elderly may be better explained through changes in functional abilities, as markers of differing interactions between the healthy and frail individuals and their environments, than chronological age. These findings provide support for concepts of system-specific patterns of aging (Cerella, 1990; Welford, 1981, 1985; Woollacott, 1989).

Although an attempt was made to tap into strength abilities on the psychomotor task through the use of ballistic actions as well as a small wrist weight, no significant differences were found between resistance conditions. Resistance provided in the present study may not have been great enough to provoke changes in the execution of the movements. It may also be that changes in force production requirements do not increase the level of
movement complexity and do not require adjustments in the movement execution (Ivry, 1986).

Correlational Data

Of particular interest in this investigation were the significant correlations between psychomotor and physical functioning measures. Stronger subjects had faster MTs and produced more peak velocity, indicating a connection between strength and psychomotor measures. This finding does not support the findings of Goggin, et al. (1993), who found that stronger subjects had slower MTs. However, the healthy and frail groups in the present investigation were much more distinct than those in the Goggin et al. (1993) study.

Correlational data on performance measures may prove extremely useful in providing information on subgroups of the growing elderly population. The findings of the present study indicate that ADL scales are not adequate for differentiation among the levels of functioning of community-dwelling populations. Only two of the frail subjects in this investigation required any assistance with three or fewer ADLs. All subjects in the present investigation were deemed to be functioning adequately by the ADL scale of the OARS assessment. Yet differences in the quality of simple gross movements were apparent between groups. Frail subjects were more likely than healthy subjects to require assistance in the task of sitting or rising from a chair, e.g., leaning on the chair or table to
complete those actions. Assessment of physical abilities through the use of a simple functional assessment tool such as that used in this investigation (Tikeiksaar, 1989) may better distinguish between levels of physical functioning in the community-dwelling elderly.

Conclusions

In support of the stated hypotheses, this investigation found significant differences between groups of healthy and frail elderly women on both psychomotor and physical functioning assessments. Healthy subjects demonstrated higher performance levels on all tasks than did frail subjects, though the groups were not significantly different in chronological age. A positive relationship appears to exist between psychomotor performance and strength. Further study is necessary in order to better understand the parameters of that relationship as well as investigate the effects of resistance training on psychomotor performance. Healthy and frail elderly women clearly performed differently across the tasks of this study. Those performance differences must be studied further to be understood. Older adults are able to benefit from resistance training in terms of strength benefits (Fiatarone et al., 1990; Frontera et al., 1988), but the effects on psychomotor performance and other functional performance abilities is unclear.
Future Directions

The difficulty of defining frail populations can not be overstated. Clinical measures do not provide useful distinctions between groups of community-dwelling elderly individuals. Simple functional assessments provide ease of administration and a demonstration of movement difficulties experienced by subjects. Future investigations would benefit from utilizing such functional assessments to supplement self-report measures.

The effects of exercise on longevity and quality of life may be complicated by the different ages at which exercise was begun, as well as the type of exercise (aerobic or anaerobic) performed and the methodology used for assessment. Many studies rely on self-report measures of assessment. Guralnik, Branch, Cummings and Curb (1989) point out the need to develop and utilize physical performance measures in conjunction with self-reports. In future investigations, systematic questioning regarding mode, frequency, intensity, and duration of exercise will provide useful information about community-dwelling healthy and frail populations of older adults. A majority of subjects in the present investigation, healthy and frail alike, reported participation in regular exercise regimens. It would be extremely useful in future studies to take a detailed exercise and illness history of elderly subjects to track patterns of physical activity and the potential
effects of those patterns on psychomotor functioning.

Future studies might provide more than one resistance condition, utilizing various amounts of resistance in movement conditions, to investigate whether changes in the amount of resistance to be overcome affect movement complexity. The physiological component of strength is moderately related to psychomotor functioning and appears to have differing effects across healthy and frail samples. This finding merits further exploration through strength training studies involving healthy and frail older adults. Correlations between the psychomotor performance measures and physical performance measures, as well as correlations between the physical performance measures themselves (e.g., grip strength and items of the functional assessment), should be further investigated. An expansion of the Fiatarone et al. (1990) study is warranted, utilizing both healthy and frail populations, pre/post-intervention evaluation on psychomotor and gross motor abilities, and resistance training involving both upper and lower body muscle groups. Results of the Fiatarone et al. (1990) study indicate that strength increases result in greater mobility and increased ease of mobility. Strength increases may also benefit psychomotor movement quality.
APPENDIX A

FUNCTIONAL ASSESSMENT
Functional Assessment

Sit Down/Rise From Chair (Coordination)
Poor 1 2 3 4 5 6 7 Excellent

Walk in a Straight Line
Poor 1 2 3 4 5 6 7 Excellent

(note stride length, height of step, and arm swing)

Climb/Descend Stairs
Poor 1 2 3 4 5 6 7 Excellent

Stand on Tiptoes and Reach Arms Upward
Poor 1 2 3 4 5 6 7 Excellent

Bend Down and Pick Up an Object From the Ground
Poor 1 2 3 4 5 6 7 Excellent

Lie Prone on the Ground and Get Up Unassisted
Poor 1 2 3 4 5 6 7 Excellent

Items from Tideiksaar (1989) article on falls among elderly populations.
APPENDIX B

SUBJECT QUESTIONNAIRE
Subject Questionnaire (w/OARS ITEMS)

Name______________________________

Date of Interview__________________________

Time of Interview__________________________
  Ended _______________________

Interviewer's Name_____________________

PRELIMINARY QUESTIONNAIRE

1. What is the date today? (M,D,Y)______________

2. What day of the week is it?______________

3. What is the name of this place?______________

4. How old are you?________________________

5. When were you born?_______________________

6. What was your mother's maiden name?________

Race of Subject
1 Caucasian
2 Black
3 Oriental
4 Spanish American (surname)
5 American Indian
6 Other
- Not answered

How far have you gone in school?
1 0-4 years
2 5-8 years
3 High school incomplete
4 High school completed
5 Post high school, business or trade school
6 1-3 years college
7 4 years college completed
8 Post graduate college
- Not answered

PHYSICAL HEALTH

Let's talk about your health now.

About how many times have you seen a doctor during the past 6 mos. other than as an inpatient in a hospital? Exclude Psychiatrists
38. During the past six months how many days were you so sick that you were unable to carry on your usual activities—such as going to work or working around the house?
   0 None
   1 A week or less
   2 More than a week but less than one month
   3 1-3 months
   4 4-6 months
   - Not answered

39. How many days in the past six months were you in a hospital for physical health problems?
   __________ Days

40. How many days in the past six months were you in a nursing home, or rehabilitation center for physical health problems?
   __________ Days

41. Do you feel that you need medical care or treatment beyond what you are receiving at this time?
   1 Yes
   0 No
   - Not answered

42. I have a list of common prescription medicines that people take. Would you please tell me if you've taken any of the following in the past month.

[CHECK "YES" OR "NO" FOR EACH MEDICINE.]

<table>
<thead>
<tr>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>YES</td>
<td>NO</td>
</tr>
</tbody>
</table>

- Arthritis medication
- Prescription pain killer (other than above)
- High blood pressure medicine
- Pils to make you lose water or salt (water pills)
- Digitalis pills for the heart
- Nitroglycerin for chest pain (tablets or patches)
- Blood thinner medicine (anticoagulants)
- Drugs to improve circulation
- Insulin injections for diabetes
- Pils for diabetes
- Prescription ulcer medicine

43. What other prescription drugs have you taken in the past month?
   [RECORD THE "others", THEN ENTER THEM IN APPROPRIATE CATEGORIES ABOVE IF POSSIBLE.]
   [SPECIFY.]

44. Do you have any of the following illnesses at the present time?
   [CHECK "YES" OR "NO" FOR EACH OF THE FOLLOWING. IF "YES" ASK: "How much does it interfere with your activities, not at all, a little (some), or a great deal?" AND CHECK THE APPROPRIATE BOX.]
   [IF "YES", ASK:] How much does it interfere with your activities?

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>YES</td>
<td>NO</td>
<td>NOT AT ALL</td>
<td>A LITTLE</td>
</tr>
</tbody>
</table>

- Arthritis or rheumatism
- Glaucoma
- Asthma
- Emphysema or chronic bronchitis
- Tuberculosis
- High blood pressure
- Heart trouble
- Circulation trouble in arms or legs
15. Do you have any physical disabilities such as total or partial paralysis, missing or non-functional limbs, or broken bones?
   0 No
   1 Total paralysis
   2 Partial paralysis
   3 Missing or non-functional limbs
   4 Broken bones
   5 Not answered

16. How is your eyesight (with glasses or contacts) - excellent, good, fair, poor, or are you totally blind?
   1 Excellent
   2 Good
   3 Fair
   4 Poor
   5 Totally blind
   6 Not answered

7. How is your hearing - excellent, good, fair, poor, or are you totally deaf? [WITHOUT HEARING AID.]
   1 Excellent
   2 Good
   3 Fair
   4 Poor
   5 Totally deaf
   6 Not answered

8. Do you have any other physical problems or illnesses at the present time that seriously affect your health?
   1 Yes
   2 No
   3 Not answered

   [IF "YES" SPECIFY]

SUPPORTIVE DEVICES AND PROSTHESSES

9. Do you use any of the following aids all or most of the time?
   [CHECK "YES" OR "NO" FOR EACH AID.]

   1. Cane (including tripod-tip cane)
   2. Walker
   3. Wheelchair
   4. Leg brace
   5. Back brace
   6. Artificial limb
<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hearing aid</td>
<td></td>
</tr>
<tr>
<td>Colostomy equipment</td>
<td></td>
</tr>
<tr>
<td>Catheter</td>
<td></td>
</tr>
<tr>
<td>Kidney dialysis machine</td>
<td></td>
</tr>
<tr>
<td>Other e.g., dentures (SPECIFY.)</td>
<td></td>
</tr>
</tbody>
</table>

1. Do you need any aids (supportive or prosthetic devices) that you currently do not have?
   - 1 Yes
   - 0 No
   - Not answered
   [IF "YES", ASK a.]
   a. What aids do you need? [SPECIFY.]

2. Do you have a problem with your health because of drinking or has your physician advised you to cut down on drinking?
   - 1 Yes
   - 0 No
   - Not answered

3. Do you regularly participate in any vigorous sports activity such as hiking, jogging, tennis, biking, or swimming?
   - 1 Yes
   - 0 No
   - Not answered

4. How would you rate your overall health at the present time—excellent, good, fair, or poor?
   - 3 Excellent
   - 2 Good
   - 1 Fair
   - 0 Poor
   - Not answered

5. Is your health now better, about the same, or worse than it was five years ago?
   - 2 Better
   - 1 About the same
   - 0 Worse
   - Not answered

5. How much do your health troubles stand in the way of your doing the things you want to do—not at all, a little (some), or a great deal?
   - 2 Not at all
   - 1 A little (some)
   - 0 A great deal
   - Not answered
ACTIVITIES OF DAILY LIVING

I'd like to ask you about some of the activities of daily living, things we all need to do as a part of our daily lives. I would like to know if you can do these activities without any help at all, or if you need some help to do them, or if you can't do them at all.

Do you require any assistance with your day-to-day activities?
(list examples from questions)

IF YES, ASK SPECIFIC QUESTIONS 56-70

Instrumental ADL

56. Can you use the telephone...
   2 without help, including looking up numbers and dialing;
     1 with some help (can answer phone or dial operator in
      an emergency, but need a special phone or help in get-
      ting the number or dialing); or
     0 are you completely unable to use the telephone?
     - Not answered

57. Can you get to places out of walking distance...
   2 without help (drive your own car, or travel alone on buses, or taxi);
   1 with some help (need someone to help you or go with
     you when traveling); or
   0 are you unable to travel unless emergency arrangements
     are made for a specialized vehicle like an ambulance?
     - Not answered

58. Can you go shopping for groceries or clothes (ASSUMING SUBJECT HAS TRANSPORTATION)...
   2 without help (taking care of all shopping needs yourself, assuming you had transportation);
   1 with some help (need someone to go with you on all shopping trips); or
   0 are you completely unable to do any shopping?
   - Not answered

59. Can you prepare your own meals...
   2 without help (plan and cook full meals yourself);
   1 with some help (can prepare some things but unable to
     cook full meals yourself); or
   0 are you completely unable to prepare any meals?
     - Not answered

60. Can you do your housework...
   2 without help (can clean floors, etc.);
   1 with some help (can do light housework but need help
     with heavy work); or
   0 are you completely unable to do any housework?
     - Not answered

61. Can you take your own medicine...
   2 without help (in the right dose at the right time);
   1 with some help (able to take medcine if someone pre-
     pares it for you and/or reminds you to take it); or
   0 are you completely unable to take your medicine?
     - Not answered

62. Can you handle your own money...
   2 without help (write checks, pay bills, etc.);
   1 with some help (manage day-to-day buying but need help
     with managing your checkbook and paying your bills); or
   0 are you completely unable to handle money?
     - Not answered
Physical ADL

13. Can you eat...
   2 without help (able to feed yourself completely);
   1 with some help (need help with cutting, etc.); or
   0 are you completely unable to feed yourself?
   - Not answered

14. Can you dress and undress yourself...
   2 without help (able to pick out clothes, dress and undress yourself);
   1 with some help or
   0 are you completely unable to dress and undress yourself?
   - Not answered

65. Can you take care of your own appearance, for example combing your hair and (for men) shaving...
   2 without help;
   1 with some help; or
   0 are you completely unable to maintain your appearance yourself?
   - Not answered

66. Can you walk...
   2 without help (except from a cane);
   1 with some help from a person or with the use of a walker, or crutches, etc.; or
   0 are you completely unable to walk?
   - Not answered

67. Can you get in and out of bed...
   2 without any help or aids;
   1 with some help (either from a person or with the aid of some device); or
   0 are you totally dependent on someone else to lift you?
   - Not answered

68. Can you take a bath or shower...
   2 without help;
   1 with some help (need help getting in and out of the tub, or need special attachments on the tub); or
   0 are you completely unable to bathe yourself?
   - Not answered

69. Do you ever have trouble getting to the bathroom on time?
   2 No
   0 Yes
   1 Have a catheter or colostomy
   - Not answered

   [IF "YES" ASK a.]
   a. How often do you wet or soil yourself (either day or night)?
      1 Once or twice a week
      0 Three times a week or more
      - Not answered

70. Is there someone who helps you with such things as shopping, housework, bathing, dressing, and getting around?
   1 Yes
   0 No
   - Not answered

   [IF "YES" ASK a. AND b.]
   a. Who is your major helper?
      Name __________________________________ Relationship ___________________
Do you exercise on a regular basis?  
Type and frequency per week  
Are you involved in other leisure activities (e.g., gardening)?  
Type and amount of activity per week  
Do you currently work?  
Type and hours per week  
Residence:  Independent community dwelling  
Congregate (age-segregated) dwelling  
Institutional  

GRIP STRENGTH (lbs)  
Right  
Left  

All items of the subject questionnaire, other than those found on page 61, have been taken (with permission) from the Older Americans Research and Service Center Instrument (OARS), developed at Duke University (1978).
APPENDIX C

CONSENT FORM
Effects of Strength on Selected Psychomotor Performances of Elderly Females

The University of North Texas

Consent to Participate in a Research Study

You have been asked to participate in a research study which will examine the relationship between strength and various motor performance measures. The information obtained in this study may provide valuable information concerning the relationship between strength and motor performance in older women.

I hereby consent to participate in Rhonda Meyer's study of "Effects of Strength on Selected Psychomotor Performances of Elderly Females". I fully understand that I will be performing a light warm-up, followed by a hand grip strength exercise. A five-minute rest period will take place before I am asked to perform a simple fine movement task. In addition, the exercises which I am going to perform have been demonstrated for me. I have also been fully informed of the risks (e.g., muscle soreness, increased blood pressure during muscle contraction) involved in the strength testing procedure. I have been informed that information given by me to the experimenter is confidential and that I will not be referred to by name in any subsequent publications or presentations of the research. I understand that I am free to withdraw this consent at any stage of this study.

If I have any questions or problems that arise in connection with my participation in this study, I should contact Rhonda Meyer, the principal investigator at 565-2651 (Work) or 387-5955 (Home).

I, ____________________________, have read the above and have decided to participate in the study described above. My signature also indicates that I understand the contents of this consent form. A copy of this form will be provided to me.

_____________________________  ________________
Signature                     Date

Principal Investigator

THIS STUDY HAS BEEN REVIEWED BY THE UNIVERSITY OF NORTH TEXAS COMMITTEE FOR THE PROTECTION OF HUMAN SUBJECTS (Phone: 565-3940).
APPENDIX E

ACCELERATION PROFILES
Acceleration Profiles
Easy Condition--Weight

Acceleration (cm/sec/sec)

- Healthy1
- Frail1
- Healthy2
- Frail2

Time (ms)

0 250 500 750 1,000 1,250 1,500 1,750 2,000
Acceleration Profiles
Hard Condition

Acceleration (cm/sec/sec)

- Healthy1
- Frail1
- Healthy2
- Frail2

Time (ms)
0 250 500 750 1,000 1,250 1,500 1,750 2,000
-1,200 -800 -400 0 400 800 1,200
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