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The Effect of Upper Body Strength Training on the Chair Rise Performance of Institutionalized Older Adults

By
Christopher W. Koolage

Submitted To
The Faculty of Graduate Studies
In Partial Fulfillment of the Requirements for the Degree

Master of Science

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Faculty of Physical Education and Recreation Studies
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Christopher W. Koolage

A Thesis/Practicum submitted to the Faculty of Graduate Studies of The University of Manitoba in partial fulfillment of the requirements of the degree of Master of Science

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ABSTRACT

Research suggested that very frail older adults may not have enough strength to rise from a chair, and that upper body strength training may improve physical performance. This study examined the effect of upper body strength training on the chair rise performance of institutionalized older adults.

Residents from the personal care units at Deer Lodge Centre were recruited. The 15 residents who agreed to participate were randomly assigned to either an experimental or control group. All residents performed tests of maximum and self-paced chair rise performance time, as well as upper and lower body strength. The seven week strength training intervention included two exercises, the bench press and seated row, and residents were required to perform 3 sets of 8 repetitions for each exercise. Those in the control group performed primarily non-physical activities including the development of "life albums" (personal scrap books).

Strength increased in the seated row, but not the bench press, and there was no change in residents' chair rise performance times. Residents trained at higher intensities and with greater loads on the seated row as compared to the bench press.

In conclusion, those who agreed to participate were not as frail as anticipated and did not have as much theoretical potential to improve in chair rise performance as expected. The non-significant change in bench press strength was attributed to the inability to train at a sufficient intensity or appropriate loads. Without increasing upper body strength, particularly bench press strength, the effect of strength on chair rise performance was inconclusive.

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INTRODUCTION

Numerous benefits of strength training in older adults have been reported, including: strength gains (Lexell *et al.*, 1995; Fiatarone *et al.*, 1993; Charette *et al.*, 1991; Brown *et al.*, 1990; Fiatarone *et al.*, 1990; and Fontera *et al.*,1988) decreased diastolic and systolic blood pressure (Kelley and Kelley, 2000), and enhanced quality of life (Singh *et al.*, 1997), among others. The vast majority of research has been carried out with community dwelling older adults, and much less attention has been given to institutionalized frail older adults. The work of Fiatarone *et al.* (1993, 1990) is a notable exception, as their research focused on lower body strength training for older adults in institutionalized settings.

Other than the work of Mihalko and McAuley (1996), research on upper body strength training with frail older adults has received limited attention. Upper body strength may play a significant role in the ability of institutionalized older adults to safely rise from and return to a seated position, and to shift positions while sitting, as well as perform other upper limb tasks necessary for ADL. Insufficient strength to lift oneself from a chair leads to otherwise ambulatory frail older adults becoming prisoners in their chairs (Kerr *et al.*, 1997). Such older adults are dependent on assistance from health care workers and invariably spend a large portion of their day waiting for such assistance. Difficulty rising from a chair is not unexpected as it may be the most demanding daily functional task for many older adults (Riley *et al.*, 1997). Studies have found that residents of personal care homes who can rise from a chair are more likely to use their arms than not (Bassey *et al.*, 1992; and Fiatarone *et al.*, 1990). It is not surprising that rising from a seated position is a difficult and sometimes impossible challenge for frail individuals. Interventions that restore the ability to rise from a chair may therefore promote independence and quality of

life for personal care home residents.

Rising from a chair involves a variety of physical attributes including strength, flexibility, and balance. Several of these attributes are modifiable, including strength, which has been identified as a limiting factor for frail older adults when rising from a low seat (Alexander *et al.*, 1997). As indicated earlier, even frail older adults can gain strength through appropriate strength training interventions. At present, most studies include lower body rather than upper body strength training, although, for personal care home residents it can be argued that an equally important intervention may be upper body strength training. Mihalko and McAuley (1996) reported significant increases in upper body strength, as well as improvements in physical performance from upper body strength training, in institutionalized frail older adults. However, in this study physical performance was measured by proxy reports and a cumulative score derived from several tasks. Only one of the 20 tasks was chair rise performance. To date, studies have not specifically examined the effect of strength gains through upper body strength training and improved chair rise performance among frail older adults in personal care homes.

Purpose of the study

The purpose of this research was to examine the effect of upper body strength training on chair rise performance among personal care unit residents.

Objectives

The first objective was to improve maximum upper body strength with a structured strength training intervention. The second objective was to determine whether increased strength improved chair rise performance time.

Hypotheses

1. The strength of those who participated in strength training would increase as compared to the strength of the control group.
2. Chair rise performance would increase for those who participated in strength training, as compared to the chair rise performance time of the control group.

Delimitations

This study included 15 residents from personal care units in Deer Lodge Centre. A common characteristic was military service during World War II, as 11 of the 15 residents were male veterans. Generalizations must be limited to senior citizens (65 years or older) who are weight bearing, able to use both arms to reach and grasp, medically stable, and capable of following simple instructions. Statements about strength and strength changes are restricted to tests of One Repetition Maximum (1RM) performed on commercially available weight training equipment.

Limitations

1. Strength was assessed with a test of one repetition maximum (1RM).
2. Chair rise performances were performed with a chair typically found in Deer Lodge Centre dining rooms.
3. Data on the daily amount of arm use, physical activity, or motivation of the residents were not collected.
4. Post-test maximum strength and chair rise performance times were assessed by research assistants who were not blinded to group composition.
5. The overall time spent with each resident was not recorded.
6. The study was limited to seven weeks in duration.

Definitions

ACSM: American College of Sports Medicine.

ADL: Activities of Daily Living, such as: eating, grooming, bathing, dressing and toileting (Katz, 1963).

Anterior: Toward of; at the front (Vander *et al.*, 1994).

Disability: Limitation in performance of socially defined roles and tasks within a socio-cultural and physical environment (Nagi, 1991).

Functional limitation: Limitation in performance at the level of the whole organism or person (Nagi, 1991).

Impairment: Anatomical, physiological, mental, or emotional abnormalities or loss (Nagi, 1991).

Maximum strength refers to 1RM values expressed in kilograms.

MMSE: Mini-Mental State Exam, developed to screen for cognitive impairment by Marshal Folstein et al. (1975). Low scores represent greater cognitive impairment, and the highest possible score is 30.

Pathology: Interruption or interference with normal processes, and efforts of the organism to regain normal state (Nagi, 1991).

PFLC: Professional Fitness and Lifestyle Consultant. A certification program of the Canadian Society for Exercise Physiology (CSEP).

Physiological capacity: Amount of a basic physical attribute, such as muscular strength, cardiovascular endurance, coordination, balance, that a person can generate (Wagner *et al.*, 1992).

Physical function (noun): A task to be physically performed.

Physical function (verb): is the integration of physiological capacity and physical performance capability mediated by psychosocial factors (Cress *et al.*, 1996). Traditionally refers to ADL, Independent Activities of Daily Living (IADL), and Advanced Activities of Daily Living (AADL).

Physical performance: The ability to integrate physical attributes into coordinated, efficient movements to achieve optimum physical function (Cress, *et al.*, 1996).

Posterior: Back of, at the back (Vander *et al.*, 1994).

Repetition Maximum (RM): Represents maximum amount of weight that a person can lift for a specified number of repetitions, for example, a 1RM is the maximum weight that can be lifted once (PFLC).

REVIEW OF LITERATURE

Introduction

Three general areas of research are reviewed in the following chapter. The first area is research on the relationship between strength and physical performance, including: conceptual frameworks, the relationship between impairment and functional limitation, and the relationship between strength and chair rise performance. Research related to strength testing and training of older adults constitutes the second area. The third area includes research related to physical performance measures, physical performance measures versus self-reports, measurement of chair rise performance time, chair rise protocols and the reliability of chair rise tests.

Conceptual Framework

Two theoretical frameworks are pertinent to the present study: the Disablement Process developed by Verbrugge and Jette (1994), and the Integrated Model of Physical Function presented by Cress *et al.* (1995). The model of the disablement process was selected to guide the present study because it was amenable to a rehabilitation intervention.

The framework posited by Verbrugge and Jette (1994) identified the relationship between pathology, impairment, functional limitation, and disability (see Figure 1.1). The disablement process is a consequence of pathology, an interruption or interference with normal processes and efforts of the organism to regain a normal state. Pathology leads to impairment, which is an anatomical or physiological abnormality, dysfunction or loss. Impairment is expressed in the form of functional limitation, a restriction in one or

more discrete actions, tasks, or functions at the level of the person. These restrictions lead to disability, that is problems in doing daily activities within a social context.

THE MAIN PATHWAY			
PATHOLOGY (diagnosis of disease, injury, congenital/ developmental condition)	IMPAIRMENT (dysfunctions and structural abnormalities in specific body systems: musculoskeletal, cardiovascular, neurological, etc.)	FUNCTIONAL LIMITATION (restrictions in basic physical and mental actions: ambulate, reach, stoop, climb stairs, produce intelligible speech, see standard print, etc.)	DISABILITY (difficulty doing activities of daily life: job household management, personal care, hobbies, active recreation, clubs, socializing with friends and kin, childcare, errands, sleep, trips, etc.)

Figure 1.1 The main pathway from health to disability (Verbrugge and Jette, 1994).

This model makes a distinction between discrete actions (or tasks or functions), and more integrated daily activities that require multiple actions (or tasks or functions). Discrete actions are associated with functional limitations whereas integrated activities are related to disability. This distinction is relevant for the present research because rising from a chair is a discrete action and difficulty performing this action falls under the domain of functional limitation.

The integrated model of physical function consists of three intersected rings that represent physiological capacity, physical performance, and psychosocial factors, with physical function at the intersection (Cress *et al.*, 1995). Physiological capacity refers to the amount of a basic physical attribute, such as muscular strength, cardiovascular endurance, coordination, or balance, that a person can generate (Wagner *et al.*, 1992). Any reduction in physiological capacity due to dysfunction and structural abnormality would be, by definition, impairment. Measuring impairment makes use of tests of

strength, flexibility, maximal oxygen uptake (VO_2max), and other physical attributes. Physical performance is the ability to integrate physical attributes into coordinated efficient movements (Cress *et al.*, 1995). Poor physical performance corresponds to functional limitation, and is measured by the difficulty to perform discrete tasks, like rising from a chair or picking up an object off the floor. Physical function can be considered to be the ability to integrate a number of discrete tasks into fluid movement, mediated by psychosocial factors. The inability to produce fluid movement resulting from poor physical performance is considered disability. Disability is measured as the difficulty in performing integrated tasks such as dressing, grooming, shopping and so on.

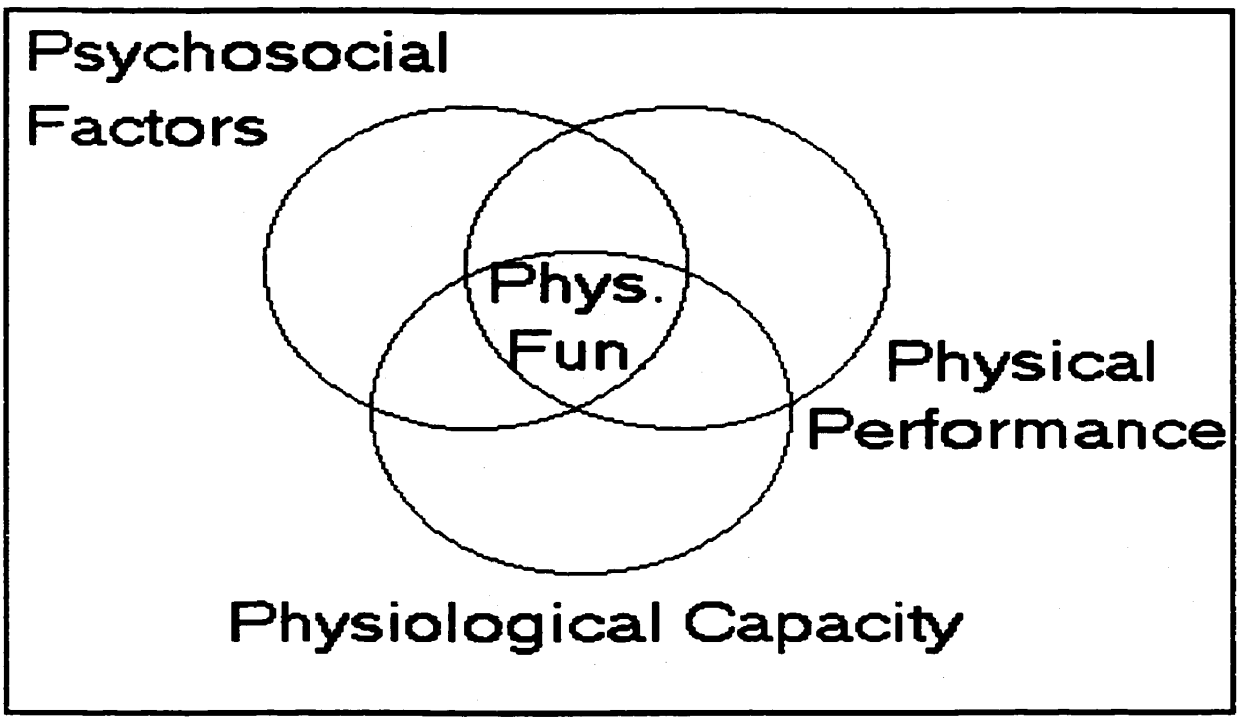

Figure 1.2 This figure represents physical function, the integration of physiological capacity, and physical performance capability mediated by psychosocial factors (Cress *et al.*, 1995).

The integrated model of physical function is conceptually similar to the disablement process framework by Verbrugge and Jette (1994) except for a few features. The integrated model is non-linear and instead projects the interaction of physiological

capacity (impairment), physical performance (functional limitation), and physical function (disability). An added feature is the recognition of the role of psychosocial factors in physical function.

Influence of Impairment on Functional Limitation

Young (1986) was one of the first to describe the relationship of impairment and functional limitation. He described physical tasks as having 'thresholds', or minimum requirements of physiological capacity to complete tasks. Based on the literature at the time, he posited that healthy 80 year-olds had small reserves of physiological capacity between normal values and crucial threshold values of rising from a low armless chair. The consequence of reduced physiological capacity is that everyday activities may become impossible, or so difficult that their performance is unpleasant.

Relationship Between Strength and Physical Performance

A model for enhancing one's intrinsic capabilities in order to interrupt the pathway to disability was proposed by Buchner *et al.* (1992). This model was later modified by Schwartz (1997) (see Figure 1.3). The new model was developed on the premise that the relationship between physiological capacity and physical performance is curvilinear. According to this model, restoring physiological capacity reverses impairment and subsequently improves physical performance. In the region of the curve marked B, changes in physical performance are proportional to changes in physiological capacity. In regions A and C however, changes in physiological capacity (e.g., strength) are not accompanied by much change, if any, in physical performance. Due to the change in

slope at the upper portion of region B, it is comparable to region C where changes in strength produce little change in physical performance.

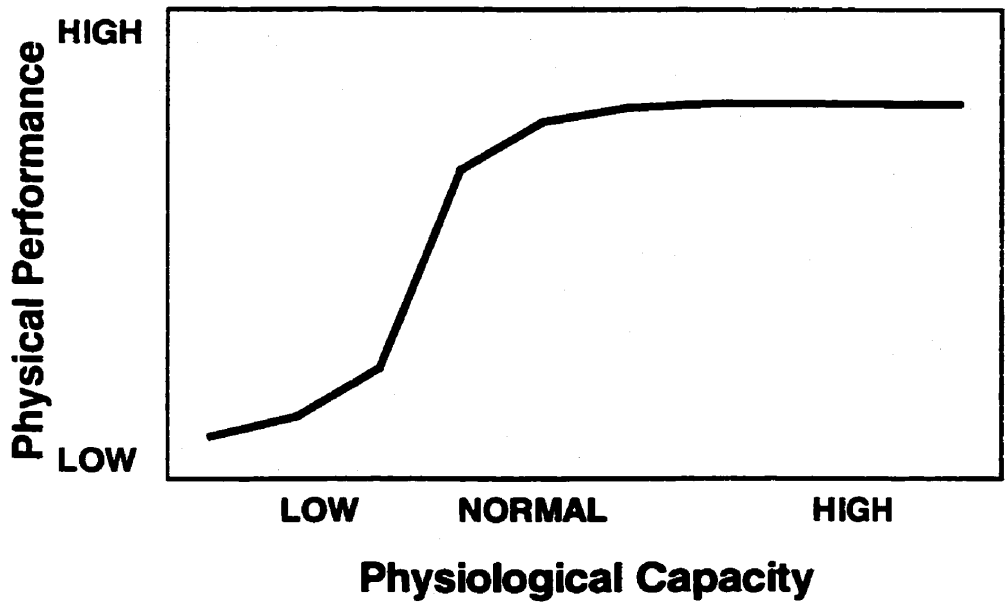

Figure 1.3 The theoretical relationship between Physiological Capacity and Physical Performance (Schwartz, 1997).

Furthermore, the plateau at the bottom of the curve (known as the "toe" region) suggests that restoring physical function in a population of people who are frail may require substantial increases in strength.

Evidence that supported this model was provided by researchers who investigated the relationship between changes in strength and physical performance in frail older adults (Mihalko and McAuley, 1996; Fiatarone *et al.*, 1993; and Fiatarone *et al.*, 1990). In an eight week pilot study of 10 personal care home residents, researchers found that high intensity strength training increased quadriceps strength by 174 ± 31% and 180 ± 33% in dominant and non-dominant legs, respectively (Fiatarone *et al.*, 1990). Improvements in walking speed achieved statistical significance but tandem foot stand did not. Clinically

significant changes were also noted, as two residents no longer used canes when walking, and one of the three residents who were not able to rise from a chair without their arms became able to do so. In a larger study, strength gains ranging from 26.1 ± 14.4% in right leg press, to 178.8 ± 29.1% in right hip extensors, were found in personal care residents (Fiatarone *et al.*, 1993). As for the functional outcomes, both gait velocity and stair climbing power increased significantly, and four residents were able to use canes instead of walkers. Another study selected frail older adults from seniors centers and nursing homes (Mihalko and McAuley, 1996). Participants performed five upper body exercises: incline bench press (for pectorals), one arm dumbell row (for latissimus dorsi), front or side lateral raises (for deltoids), biceps curls (for biceps), and triceps press (for triceps). Maximum strength was calculated by summing the 1RM for each exercise. Physical performance was determined by the primary caregiver who rated the participants on a 7 point Likert scale from 1 (cannot do) to 7 (can do easily) for 20 different tasks. Chair rise performance was included as one of the 20 tasks. Maximum strength increased significantly by no less than 50% for each exercise. Physical performance demonstrated a marked increase in the strength training group with a significant main effect and a decrease in the score of the control group.

These findings indicate that physical performance can be improved by restoring upper and lower body strength. However, as the model presented by Schwartz (1997) indicates, changes in physical performance may require large changes in strength, and those with good theoretical potential for improvement in physical performance are in the low to mid-normal portion of the curve.

Relationship Between Strength and Rising from a Chair

While examining the role of leg strength on chair rise performance, two studies found that functional limitations were a consequence of lower limb weakness (Hughes and Schenkman, 1996; and Schenkman *et al.*, 1996). These investigators found that leg strength determined the lowest height chair height from which participants could rise without their arms. Hughes and Schenkman (1996) compared the chair rise performance of young healthy individuals to that of older individuals who had moderate functional limitation (in stair descent), on a number of chairs varying in height. Older adults (n=11) were unable to rise from the two lowest chair heights (0.33 and 0.38m). Moreover, they used 97 +/- 22.5% of maximum isometric quadriceps strength when rising from the lowest successful chair height (0.43m for 4 adults, 0.48m for 3 adults, and 0.53 for 2 adults). The young group could rise from the lowest chair height, and only required 39 +/- 8% of their total isometric quadriceps strength. The authors reported that decreasing chair height linearly increased the joint moment required to rise from a chair.

Schenkman *et al.* (1996) found that a lower body strength index correlated well to the lowest chair height from which participants could rise (R^2 of 0.49). The strength index included the strength of both flexors and extensors for the knee and ankle joints made relative to body weight, and adjusted to compensate for the difference in torque available between muscles. The significant correlation was found after covariation for proprioceptive ability, vibratory sense, and ankle joint range of motion.

The aforementioned research demonstrated that knee strength was a limiting factor for older adults when trying to rise from a low chair without using arms. Those who participated were functionally limited based on the inability to descend four consecutive

stairs, step over step without using the handrail. This definition of functional limitation would likely have permitted inclusion of people who are more physically functional than the very frail. As a result, these findings may have underestimated the importance of strength when rising from a chair, especially for residents of personal care homes who are the frailest of frail.

Although leg strength determines the lowest chair from which older adults can rise, most people can utilize more than their leg muscles to stand from a chair. The role of arm use in rising from a chair was examined in two studies (Alexander *et al.*, 1991; and Schultz *et al.*, 1992). The first study examined the chair rise performance of three groups: the young, the old able (can rise from a chair without using arms) and the old unable (cannot rise from a chair without using arms) (Alexander *et al.*, 1991). Data from that study revealed that the old unable group experienced more difficulty rising from a chair as they required a significantly longer time to rise.

In the companion publication of the preceding research, investigators elaborated on arm use during chair rise performance (Schultz *et al.*, 1992). They determined joint torque requirements and found that rising from a chair required 39Nm from ankle plantar flexors, 119Nm from knee extensors, 96Nm from hip extensors and 37Nm from shoulder flexors. Based on a review of strength measurements from existing experiments, none of which included institutionalized older adults, the researchers concluded that these values were not difficult for typical elderly populations to produce. As a result, it remained to be seen whether very frail older adults could generate the forces required as easily as typical elderly people.

Data from this study also demonstrated that when participants used their hands, they "chose" to propel their center of mass into a balanced position by producing forces at 50 degrees to the horizontal (Schultz *et al.*, 1992). Because the participants did not produce their forces more vertically, which would reduce 3 of the 4 joint torque requirements, the authors concluded that use of hands in rising from a chair is for balance, not additional strength. One problem with this statement was that results from six older females originally included in the unable group were excluded from data analysis. These participants were removed because they required "substantially" longer to rise than the other 11 older females in the unable group (6s compared to 3.16s). The authors felt that these results could "bias the mean group data" (p. M92). Those who required longer to rise may be part of a population who experience more difficulty rising from a chair than the unable group. Acknowledging that there is a population more frail than that included in the analysis of their own data, these authors stated that upper body strength may be a limiting factor in rising from a chair for some frail elderly (Alexander *et al.*, 1991).

Review of Existing Chair Rise Performance Times

Young adults and healthy older adults.

Young adults reached a standing position in 1.57± 0.23 seconds when asked to rise from a chair at a comfortable pace with hand use, and 1.56± 0.31 seconds without hand use (Alexander *et al.* 1991). A similar rise time (1.56± 0.29 seconds) was reported for young adults who stood at a normal speed without hand use (Papa and Cappozo, 2000).

Healthy older adults could rise in an average of 1.56± 0.42 seconds at a comfortable pace when using hands, and 1.83± 0.71 seconds when not using hands (Alexander *et al.*

1991). Other reported chair rise performance times for healthy older adults who stood at a natural pace without hand use are: 1.44± 0.17 seconds (Vander Linden *et al.*, 1994); 1.56± 0.30 seconds (Papa and Cappozo, 2000); 1.67± 0.27 seconds (Baer and Ashburn, 1995).

Reported chair rise performance times for healthy older rising at a fast pace without hand use are: 1.19±0.20 (Vander Linden *et al.*, 1994) and 1.25± 0.27 (Papa and Cappozzo, 2000). The only reported chair rise performance time for young adults rising at a fast pace without hand use was: 1.01± 0.17 seconds (Papa and Capozzo, 2000).

Functionally impaired older adults.

Functionally impaired older adults (who could not descend stairs foot over foot) took up to 7.5 seconds to rise (Schenkman *et al.*, 1996). Another study excluded five participants from data analysis because they required substantially longer than 6 seconds to rise from a chair (Alexander *et al.*, 1991). Chair rise performance times of 3.8±4.0 seconds with hand use, and 4.6±3.4 without hand use were reported for community dwelling older adults dependent in an average of 3 mobility related ADLs (Alexander *et al.*, 2000). The last participants to be compared were: 75+ years old, 2.6±1.3 chronic conditions, 4.3±2.1 prescribed medications, and alert enough to "follow instructions". They took from 1.3 to 26.7 seconds to rise without using their arms from a "go" command. The mean chair rise time was 6.0±5.4 seconds (Mourey *et al.*, 2000).

To summarize, chair rise performance times were highly variable and they were related to the functional status of the participants, arm use, and the speed at which participants were instructed to rise.

Strength Training and Testing of Older Adults

Strength training.

High intensity strength training has consistently produced larger increases in strength than low intensity strength training (Porter *et al.*, 1995). Numerous studies have demonstrated that older adults are not constrained in their ability to adapt and produce dramatic increases in strength with high intensity training (Fiatarone *et al.*, 1993; Fiatarone *et al.*, 1990; Charette *et al.*, 1991; Brown *et al.*, 1990; and Fontera *et al.*, 1988). Of all the investigators who studied strength training, only one group of researchers had found similar improvements in strength with low and high intensity strength training (Taaffe *et al.*, 1996). In this study, baseline and final strength values (at 52 weeks) were similar between groups, indicating a similar change in strength with both high and low training intensity. However, the high intensity group had significantly larger 1RM values at three months than the low intensity group. These results suggest that high intensity training is essential to maximize strength gains in short periods of time.

The American College of Sports Medicine's (ACSM) guidelines for resistance training with elderly populations recommends that 8-12 repetitions be performed per exercise (ACSM, 1998). This repetition range was utilized by many studies that have shown marked strength gains (McCartney *et al.*, 1996; Morganti *et al.*, 1995; Pyka *et al.*, 1994; Fiatarone *et al.*, 1993 and 1990; Brown *et al.*, 1990; and Fontera *et al.*, 1988). Repetitions have varied between studies from six (Lexell *et al.*, 1995; and Charette *et al.*, 1991) to 20 (Brown *et al.*, 1990). Only one research group has varied the number of repetitions within a study. Brown *et al.* (1990) had three different repetition ranges:

bench press and arm curls were set at 10 repetitions, leg press was performed 15 times, and seated deadlifts and abdominal curls were given a range of 12-20 repetitions.

The American College of Sports Medicine recommends that older adults perform two sets per exercise with at least 48 hours of rest. However, most researchers include 2 to 4 sets per exercise while providing two to three days of rest (Mihalko and McAuley, 1996; Lexell *et al.*, 1995; Morganti *et al.*, 1995; Pyka *et al.*, 1994; Fiatarone *et al.*, 1993; Fiatarone *et al.*, 1990; Brown *et al.*, 1990; and Fontera *et al.*, 1988). One exception is the work of Charette *et al.* (1991), who increased the number of leg extension and leg press sets from three to six while keeping the other five leg exercises at three sets.

Strength training studies have also included large variations in the number of prescribed exercises. Pyka *et al.* (1994) included the following 12 exercises: knee extension and flexion, back extension, hip abduction and adduction, hip flexion and extension, leg press, bench press, military press, triceps press, and upright rows. On the other hand, some studies only included leg extensions (Fiatarone *et al.*, 1990).

Recommendations from the ACSM further state that minimal resistance be lifted during the beginning of a resistance training program (two weeks). Fiatarone *et al.* (1990) included one week of familiarization with 50% of 1RM, but these authors had no familiarization in their following study despite being two weeks longer (Fiatarone *et al.*, 1993). Other studies with progressions in intensity were: Brown *et al.* (1990), who included a progression from 2 sets at 50% 1RM to 4 sets at 70-90% 1RM; and Frontera *et al.* (1988), who provided "three practice sessions" before starting with three sets of eight repetitions at 80% of 1RM.

Evans (1999) suggested that repetitions be performed at a 6-9 second cadence, allowing 2-3s for the concentric phase and 4-6s for the eccentric phase. He stated that faster repetitions do not increase strength gains and may increase the risk for injury. Few studies have reported using a cadence. Those that have used a similar cadence to the one proposed by Evans are: (Morganti *et al.*, 1995; Fiatarone *et al.*, 1993 and 1990; and Fontera *et al.*, 1988). Charette *et al.*, (1991) chose two seconds for the concentric phase and 3 seconds for the eccentric phase, making their cadence slightly faster than that recommended by Evans.

Four studies reported providing warm-ups prior to strength training programs. Three groups of researchers incorporated 10 minute walks followed by stretching (McCartney *et al.*, 1996; McCartney *et al.*, 1995; Pyka *et al.*, 1994; and Fontera *et al.*, 1988). Lexell *et al.*, 1995 included cycling and low resistance repetitions (~50% of 1RM). Only McCartney *et al.* (1995 and 1996) reported the use of a cool down, 10 minutes of walking.

One of the most distinct features of resistance training programs found in the literature is the 10 second pause provided between repetitions in the study by Fontera *et al.* (1988). Other researchers have provided pauses between reps, but no more than three seconds was ever permitted (Morganti *et al.*, 1995; Fiatarone *et al.*, 1993 and 1990; and Fontera *et al.*, 1988. Rest between sets is generally no more than two minutes (McCartney *et al.*, 1996; Brown *et al.*, 1990; Fiatarone *et al.*, 1993 and 1990; and Fontera *et al.*, 1988).

Strength testing.

ACSM recommends the use of 1RM as a simple test of dynamic strength. However, when referring to older adults, the ACSM maintains that no ideal protocol exists. Because research typically defines loading as a percentage of 1RM, this type of testing has been used extensively. One group of researchers presented their coefficient of variation for repeated measures as being 2-5% for 1RM tests in older women (Charette *et al.*, 1991). This protocol included a 5-10 minute walk and several sets of low resistance repetitions prior to single repetitions commencing near estimated maximum strength. In addition, only 30 seconds were given between attempts and two minutes were provided between exercises.

Maximum Strength of Older Adults

The review is limited to studies that incorporated tests of 1RM for chest, back, and leg press exercises. Several of these studies have been conducted with community dwelling older adults (Taaffe *et al.*, 1999; Taaffe and Marcus, 1997; Taaffe *et al.*, 1996; Hunter *et al.*, 1995; McCartney *et al.*, 1995; Pyka *et al.*, 1994). The lowest reported bench press strength was from 17 healthy women an average age of 67± 1.2 years old (Hunter *et al.*, 1995). These women pushed an average of 14.7± 0.9kg. For participants in the other studies, bench press strength ranged up to 45kg for healthy males between the ages of 60 and 80 (McCartney *et al.*, 1995).

As for studies that included back exercises, typically the "lateral pull down" exercise, strength values ranged from 23.5± 1.3kg (Hunter *et al.*, 1995) to 41.8± 7.8kg in 11 healthy men aged 69.5± 1.0 years old on average (Taaffe and Marcus, 1997).

For leg press strength, studies reported a range from 70.4±4.4kg (Hunter *et al.*, 1995) to 152kg in 70-80 year old men (McCartney *et al.*, 1995).

Only two studies with institutionalized older adults were relevant based on strength tests for the specified muscle groups (Mihalko and McAuley, 1996; and Fiatarone *et al.*, 1993). Both of these studies were presented in an earlier section (see p. 11).

Measuring Physical Performance vs. Self or Proxy Reports

It is widely accepted that physical performance measures and self-reported measures should be used to complement each other when assessing an individual's abilities (Reuben *et al.*, 1995). Physical performance measures involve participants physically performing task(s) under assessment. Because task(s) are observed, assessors can clearly determine if the task is completed and how much difficulty, if any, participants have. As a result of this direct observation, physical performance measures have excellent face validity (Guralnik *et al.*, 1989). This validation is extremely important, because validity is otherwise incapable of being determined – at present, there is no gold standard (Cress *et al.*, 1996; Fontera *et al.*, 1988). A disadvantage of using physical performance measures is that it requires a great deal of time to assess a variety of physical abilities. In contrast, one of the benefits of self reports is the ability to assess a large number of people on a variety of physical abilities. Disadvantages of self-reports include the inability to validate responses, and the questions asked may produce misleading responses. As for the validation of responses, someone could report having the ability to walk a mile even though they have not done so in years. In terms of misleading responses, questions about the activities respondents perform (ie. do you make your bed?) do not indicate if the task

is easy, difficult or impossible. Furthermore, one may report no difficulty eating, despite not being able to, if someone else feeds them. Physical performance measures obviate the dilemma of how to word questions and which questions to ask, by asking people to physically demonstrate their ability (Guralnik *et al.*, 1989).

Cognitive impairment is likely to interfere with results from a self-report in many ways. The participant must have the cognitive ability to report that they can or cannot perform tasks (Guralnik *et al.*, 1989; and Cress *et al.*, 1996). Also, if a participant does not have the cognitive ability to perform specific tasks, such as cooking meals, it is impossible to determine the physical ability of that person to cook a meal if they were not cognitively impaired. Furthermore, if proxy is used to report the participant's physical ability, one reintroduces the dilemma of which question to ask: can a participant perform a task or does the participant perform a task? These two questions, as discussed above, can yield different answers and can be misleading.

Another benefit of physical performance tasks is that people may learn that they can physically perform a particular task better than they expected (Cress *et al.*, 1996). Self - report methods are at a disadvantage in this respect, because they do not require respondents to challenge themselves.

Measuring Chair Rise Performance Time

Researchers believe that physical performance measures provide objective data on task difficulty when time is used as a surrogate for the amount of difficulty (Guralnik *et al.*, 1989). This position was originally developed from the theory that weakness promotes an inability to sustain the most efficient movement pattern to accomplish a given task, and that the resulting inefficiency is what increases performance time (Cress *et al.*, 1996).

Research supports the use of time as an indicator of difficulty. Previously mentioned work by Alexander *et al.* (1991) demonstrated that older subjects unable to rise from a chair without the use of arms took nearly twice as long to stand up than young or healthy elderly individuals. Bassey *et al.* (1992) also found that people who required the use of arms took significantly longer to stand. Several other studies also support time as an indicator of task difficulty (Kerr *et al.*, 1997; Packer *et al.*, 1994; and Yoshida *et al.*, 1983).

Timing physical performance measures has several benefits beyond providing objectivity to task difficulty. First, timing permits greater discrimination of physical performance than self report measures. Because time is a continuous variable, one can determine differences in performance down to the tenth of a second. In contrast, self report measures are limited in their number of categories. In the worst case scenario, some instruments only permit dichotomous classifications, such as an "able/not able" style of observation or self-report (Seeman *et al.*, 1994). Second, timed measures reduce the likelihood of ceiling or floor effects. With time, there is no upper limit (ceiling

effect), unless a time limit is imposed. Similarly for floor effects, a lower limit would only occur if the participant were unable to perform the task.

Chair Rise Protocols

Chair rise tests are used in two types of research, studies that attempt to identify or classify individuals' level of physical performance, and those that examine chair rise performance mechanics.

Assessing physical performance.

Several studies have assessed or classified older adults' level of physical performance (Chandler *et al.* 1998; Davis *et al.*, 1998; Ferrucci *et al.*, 1997; Alexander *et al.*, 1995 Skelton *et al.*, 1994; McMurdo and Rennie, 1993; and Bassey *et al.*, 1992). Protocols for the "healthy elderly" vary by the number of chair rises included in the measure, the rate at which the task was performed, and whether arm use was allowed. Davis *et al.* (1998) and O'Hagan *et al.* (1995) both used the time to complete five chair stands. Davis *et al.* (1998) required participants to use their arms, while O'Hagan (1995) recorded spontaneous hand placement during maximal chair rise efforts. Gill *et al.* (1995) used the time for three chair rises done as quickly as possible, whereas Skelton *et al.* (1994) recorded the best of three individual chair rises completed at a comfortable pace. Other authors did not publish information on these parameters (Alexander *et al.*, 1995; Davis *et al.*, 1998). Two of the most consistent features of these chair rise protocols are performances without arms, and seat heights of 0.42-0.49m (Davis *et al.*, 1998; Skelton *et al.*, 1994).

Chair rise protocols included in research on the physical performance of people considered to be disabled are similar to protocols used in "healthy" populations (Ferrucci *et al.*, 1997; Bassey *et al.*, 1992). Ferrucci *et al.* (1997) required participants to attempt to stand without the use of arms. Those who could stand proceeded to stand and sit five times as fast as possible. No information was provided on the number who could not stand without the use of arms. Bassey *et al.* (1992) had participants perform three separate single trials with participants rising as fast as possible. If participants were unable to rise without their arms, their walking frame was positioned in front of them for balance once standing. The fastest trial of the three was recorded for analysis.

Chair rise performance mechanics.

Chair rise protocols used in kinematic analyses of chair rise performances primarily vary across three parameters: the number of repetitions performed, time to pause between repetitions, and body alignment. In published reports, the number of practice repetitions completed ranges from two to 10 (Kralj *et al.*, 1990; and Kerr *et al.*, 1997, repectively) while test repetitions vary from 3 to 10 successful efforts (Troy *et al.*, 2000, and Millington *et al.*, 1992, respectively).

Of the investigators who reported rest intervals between the stand and sit components, pauses of 2-3 and 3-4 seconds were given during the standing position (Kralj *et al.*, 1990; and Kerr *et al.* 1997, respectively). Rest between reps has been reported to last as long as needed when required (Kralj *et al.*, 1990), or long enough to reposition the participant (Kerr *et al.*, 1997).

Adjusting the seat to the height of the participant's knees is commonly used to control the effect of seat height by producing a standard horizontal thigh position. Knee angles are also controlled with a standard position, typically 90 degrees of knee flexion (Yoshida *et al.*, 1983; and Kralj *et al.*, 1990). However, Kerr *et al.* (1997) used 5-10 degrees from vertical toward full flexion. The problem with any angle beyond 90 degrees of flexion is that the front of the chair would restrict subjects from straightening their legs unless they took a step forward.

Reliability of Chair Rise Tests

There are few studies of intra-rater reliability of individual chair rise performances and there is even less information on the intra-rater reliability of repeated chair rising. Intra-rater reliability of a single chair rise is variable. In the literature, the lowest reported reliability, was an intra-class correlation coefficient (ICC) of –0.04 (Tappen *et al.*, 1997), and the highest value was an ICC of 0.94 (Fox *et al.*, 1996). This variation may be influenced by sample characteristics, for instance, Tappen *et al.* (1997) included participants with Alzheimer's disease and a mean Mini-Mental State Exam (MMSE) score of 9.0. The impressive ICC from Fox *et al.* (1996) was determined from a sub-sample of participants who were able to perform the chair rise without the use of arms. Those who were unable to rise without using arms were reported as demonstrating "lower agreement" (p. 174).

Repeated chair rise measures show a more stable range of results. In the two studies that examined repeated chair rise reliability, coefficients of 0.73 (Seeman *et al.*, 1994)

and 0.67 (Jette *et al.*, 1999) were reported. Participants in both of these studies performed five repeated chair rises and were retested two weeks later.

Specific issues related to chair rise performance reliability were raised by Jette *et al.* (1999). These authors purport that repeated chair rise protocols may reduce measurement error by increasing the time of the test. They also state that poor reliability on a single sit-to stand test may be attributable to difficulty in establishing the beginning and end of a test based on body movements (e.g. first trunk flexion and termination of vertical displacement). They further suggest that reliability decreases when unfamiliar tasks are performed. With older adults, standing as quickly as possible, or not using their arms, are requirements that may make a task unfamiliar. In addition, more than one instruction could be counter productive. Participants may decide that it is more important to follow one particular instruction, and their decision could change between tests.

Summary

Two models have described the relationships of the components of physical function. Impairment leads to functional limitation by reducing one's physiological capacity until task thresholds are approached or exceeded. Restoring physiological capacity can theoretically reverse functional limitations. Lower body strength is related to chair rise performance in frail older adults, and researchers speculate that very frail older adults may require the use of arms to rise from a chair. Chair rise performance times vary greatly from young adults to frail older adults.

Despite recommendations by the ACSM, researchers have varied strength training and testing protocols greatly. Physical performance can be measured with self-reported,

proxy, or direct performance measures. Timed physical performance measures offer benefits beyond objectivity in measurement. These measures have been used to assess people's chair rise ability and mechanics. The reliability of chair rise performance varies by population and the number of trials performed.

METHODS

Introduction

The present research was a component of a larger study conducted by those involved with the Interdisciplinary Summer Research Program at Deer Lodge Centre. This program is the product of collaboration of researchers at the University of Manitoba and Deer Lodge Centre. Internal funding provided by the Deer Lodge Foundation supports summer employment for 7 students or recent graduates of the University, and any equipment used in the summer research. The research itself is conducted under the supervision of the university researchers.

Ethics

Informed consent was obtained from each participant, or, when appropriate, a family member serving as a proxy. The proposed research was given ethical approval by the Committee for Research Involving Human Subjects from the Faculty of Physical Education and Recreation Studies.

Resident Recruitment and Screening

Participants were residents of the geriatric personal care units at Deer Lodge Centre, a long-term care facility in Winnipeg. A list of eligible residents was requested from the physiotherapy department and the nurse coordinator on each unit. Residents were referred if they satisfied the inclusion and exclusion criteria described below, and, in the opinion of both physiotherapists and the unit coordinators, did not face abnormal risk of injury from participating in strength training. The number of residents involved at

various phases of the study are presented in Table 3.1.

Table 3.1. Number of Residents at Each Phase of the Recruitment Process

TOTAL RESIDENTS	**N=**	**198**
ELIGIBLE RESIDENTS		41
RESIDENTS CONSENTED		21
Residents died		2
Residents were unsafe during transfer to exercise equipment		2
Resident withdrew during pre-testing		1
Resident's physical condition worsened		1
RESIDENTS PARTICIPATED		15
Randomly Assigned to Experimental Group		8
Randomly Assigned to Control Group		7

To be included, residents must have been 65 years of age or older, weight bearing without aid, capable of following simple instructions, and able to use both arms sufficiently to reach and grasp objects. A priori reasons for excluding residents were as follows: rapidly progressive or terminal illness, and acute illness or unstable chronic illness (Fiatarone *et al.*, 1993). Any other reasons for exclusion were left to the discretion of the physiotherapy department, unit coordinators, or the medical director who screened residents to ensure that they had no abnormal cardiovascular or musculoskeletal condition that may have led to injury. When residents from the Alzheimer unit were recommended, their ability to participate was additionally assessed by the investigator who asked them to perform several simple physical tasks (e.g. lift a pen eight times, rise from a chair, etc.).

Study Design

Residents were randomly assigned to the experimental or control groups. The experimental group underwent seven weeks of strength training on two exercise machines: the bench press and seated row. Research assistants (RAs) met with residents in the control group to control for the influence of individual attention. Tests were conducted the month before the intervention and in the following training. A timeline for various components of the study is presented in Table 3.2.

Table 3.2. Timeline for the various components of the study.

COMPONENT of the STUDY	WEEK
Familiarization to chair rise performance test protocols and equipment	-4
Performance measure testing	-3
First 1RM strength test	-2
Second 1RM strength test	-1
Random assignment into groups	**0**
Strength training: M,W,F	1
Strength training: M,W,F	2
Intermediate strength testing: M; Strength training: W,F	3
Holiday: M; Strength training: W,F	4
Intermediate strength testing: M; Strength training: W,F	5
Strength training: M,W,F	6
Strength training: M,W,F	7
Post-testing: Strength- M, T; Chair Rise Performance- W,T,F	8

Note. M,W,F, represent Monday, Wednesday, and Friday.

Chair rise performance tests

Each resident received a familiarization session prior to testing. The session included an explanation of both chair rise performance protocols followed by a demonstration, and ended with the resident performing a practice trial of each protocol. At pre-testing, residents were systematically assigned a test order: one resident started with one protocol, the next resident would start with the other protocol. This test order was maintained at

post-testing. To promote reliability, the investigator administered all of the chair rise performance tests.

Maximum chair rise performance.

This protocol was designed to assess residents' maximum chair rise ability without variation in leg position. To promote maximum effort, residents were instructed to perform each chair rise "as fast as possible". Residents were required to perform five chair rises with 15 seconds of rest between each rise. A rise was successful if residents reached a standing position in less than 15 seconds from the initiation of trunk flexion. Residents were permitted to make as many attempts to rise as they required, but a successful rise must have started from the specified pre-rise body positions (described below).

To perform this protocol, residents sat in a wheelchair seat fastened to a table on a hydraulic pump. The seat cushion was replaced by a stiff piece of 1" thick foam. Residents knees were visually positioned to 90 degrees. To achieve this position, the seat height was adjusted so that the thighs were parallel to the floor, and the ankles were positioned under the knees. A block was placed behind the ankles to prevent any posterior displacement during chair rise attempts. The arms were positioned so that the elbows were on the arm rests on either side, and the metacarpo-phalangeal joints were over the anterior edge of the armrest. If residents required a walker, it was placed in front of them for support once standing, but it was not permitted for assistance while in the process of rising. In addition to the instruction to rise "as fast as possible", residents were instructed to use the armrest while rising from the chair.

Self-paced chair rise performance.

This protocol was designed to assess the ability to rise from a chair in an everyday setting. Residents seated themselves in a dining room chair commonly found throughout Deer Lodge Centre. They were then instructed to rise five consecutive times at a "normal" or "everyday" pace. The time for each rise was measured. Rising and sitting technique was not manipulated, and assistive devices were permitted, but they were braced by a research assistant when required (for safety concerns). All residents used the armrests to rise from the chair.

Video recording.

A video camera was used to determine chair rise performance time. For both chair rise protocols, a Panasonic super VHS video camera was positioned at the residents' right side. Chair rise performances were recorded at 30 frames per second. Chair rise performance times for both protocols were determined by counting the number of frames between visible trunk forward flexion and the peak vertical displacement of the head. One of two criteria to the start and end positions of a chair rise performance was that any pause of greater than 20 frames (0.67s) that occurred once residents were off the seat was considered the end of that movement. This eliminated any artificial increase in chair rise performance time when residents "straightened themselves out". The other criteria related to any pause of greater than 20 frames (0.67s) while residents were seated and repeating trunk flexions in an attempt to rise. If such a pause occurred, the time to rise was restarted from zero. For instance, if a resident performed five trunk flexion motions while attempting to rise, but paused for more than 20 frames after the third, their chair

rise performance time only included the last two attempts. This criteria prevented data from being biased (with an increase in chair rise performance time) by repeated attempts.

Strength Testing

Three exercises were tested: bench press (BP), seated row (SR) and leg press (LP). All exercises were performed on commercially available weight training equipment by Hammer Strength (Life Fitness Systems) or Pulse Fitness Incorporated. The specific equipment used were: a plate-loaded IL Bench Press, a plate-loaded IL Low Row, and a horizontal double leg press.

Testing prior to the intervention included two test sessions conducted one week apart. Residents were tested on the same day in both weeks. The test order was developed by systematically assigning residents to 1 of the 6 possible combinations of three exercises (e.g., BP-SR-LP, or SR-LP-BP, etc.). Residents completed the post-test in the same order as the pre-testing. To promote reliability, two research assistants aided in conducting all the strength tests; one was responsible for the upper body exercises, the other was responsible for the leg press.

The intermediate strength tests conducted in weeks 3 and 5 were not for data analysis, but for modification of training parameters. Residents were therefore tested by the research assistant who had been assigned to them. Results were used to ensure that residents continued to train at an appropriate percentage of their maximum strength, in case their maximum strength has increased.

Strength test protocol: One repetition maximum (1RM).

In the first set, residents performed a set of eight repetitions with the lowest resistance possible (i.e., the weight of the levers alone). This set provided a warm up and familiarization to the movement. The second set included four repetitions with a weight estimated to be 50% of 1RM, and the third set was a single repetition performed with a weight estimated to be 80% of 1RM. Every set beyond the third consisted of a single repetition with progressively increasing weight until the resident was unable to continue. Because a sensitivity of 1.12N was desired, if a failed attempt occurred after an increase of more than 2.2N, the load was reduced by half, and another attempt was made. If successful, attempts continued with increments of 1.14kg until residents were unable to continue. The last successful load that could be lifted was considered the 1RM. Procedures for the first and second pre-test varied somewhat. During the second and third sets of the second pre-test, weights were derived using 50% and 80% of 1RM from residents' first pre-test 1RM instead of estimating 50% and 80% of 1RM.

Range of motion for each exercise was established during the second set as residents would exaggerate their motion in the no load warm-up set. For the bench press, "soft" (not locked) arm extension distance was recorded using rulers that had been attached perpendicularly to the frame of the bench press machine. Stringing an elastic cord from one ruler to the other across the front of the machine ensured a consistent range of motion (within and between sets). For the seated row, range of motion was visually established as the closest position of the handles to the equipment's chest pad or the resident's body. The row motion was limited in shoulder flexion to the point where the handles reached the resident's auxillary line (armpit line perpendicular to the floor). For the leg press,

range of motion was visually established as the furthest position of the foot plate at "soft" leg extension.

Despite performing the bench press and seated row bilaterally, strength was measured independently for each arm as the equipment's levers acted unilaterally.

Strength Training Protocol

Residents performed two exercises: a seated two-arm pull (i.e., seated row) and a seated two-arm chest press (i.e., bench press). Each exercise was performed three times, and each time, eight repetitions of each exercise were completed. From 1.5 to 2 minutes of passive (inactive) rest were provided between sets. Residents performed the exercises at a cadence that was most comfortable for them. Although 80% of 1RM was the desired resistance, if a resident was unable to perform eight repetitions properly at this weight during the first set, resistance was dropped to 70% for the next set. If the resident was again unable to perform eight repetitions, resistance was dropped to 60%. This procedure continued until the resident was able to perform eight repetitions. Once residents completed three sets of eight repetitions correctly, their training weight was increased "as tolerated".

The motions for both exercises were as follows. For the seated row, residents grasped the handles with an overhand grip and pulled the handles (bilaterally) toward their hips, stopping before they passed their bodies. (As with strength testing, residents were instructed not to pass their auxillary line). For the bench press, seat height was adjusted so the handles were below the armpits. Residents were encouraged to push (bilaterally) with their arms in the sagittal plane (i.e., upper arms brushing their trunk). When

returning the weight towards their bodies, residents' hands did not pass beyond the anterior aspect (i.e., past their chest). Range of motion for both exercises was visually monitored.

Control Group Protocol

Members of the control group were visited by research assistants three times a week for approximately one hour each visit. Control group activities involved primarily non-exercise tasks including the development of "life albums", or photo albums containing life stories provided by the residents. The stories were anything shared by residents and generally included memories of WWII, marriage, jobs, and friends. The stories were enhanced by the addition of photos provided by residents or their families, and when nothing was supplied, microsoft clipart and the internet were searched for relevant illustrations. There were occasions where the control group activities included walking, such as relocating from one room to another, or a couple trips to the park.

Data Analysis

Data analysis was performed with SigmaStat, version 2.03 (SPSS Inc.). The following are the variables analyzed and the statistics used for analysis.

Baseline variables.

Baseline variables include age in years, height in centimeters, body mass in kilograms, MMSE scores, length of stay at Deer Lodge Centre in months, and number of medications.

Strength variables.

Maximum strength for bench press and seated row was recorded for right and left arms, independently. Leg press was expressed as a total of both legs (pre-test strength scores were the best of two pre-tests).

Physical performance variables.

Maximum Chair Rise Performance was the minimum sit to stand time of all five attempts in protocol 1. Self-paced Chair Rise Performance was the average sit to stand time of all five rises in protocol 2.

Intensity variables.

Initial training intensity is the first weight that could be lifted successfully for three sets of eight repetitions divided by the resident's pre-test 1RM for the particular exercise, and reported as a percentage. [e.g., if a resident had a 1RM strength of 20kg and they could lift 10kg over 3 sets of 8 repetitions, their training intensity was 10/20, or 50%.]. Final training intensity is the largest weight that could be lifted for three sets of eight repetitions in the last week of the intervention divided by the resident's post-test 1RM for the particular exercise and reported as a percentage.

Volume variables.

Training volume was the product of the number of sets, repetitions completed and training load during a strength training session (e.g., 3 x 8 x 10kg = 240). Peak volume

per week was the sum of each resident's largest training volume, calculated weekly.

Analysis.

Baseline characteristics were analyzed for any difference between exercise and control groups with independent Student's t-tests. Analysis of differences in maximum strength and physical performance variables between and within groups over time was performed with repeated measures ANOVA. The significance of differences between and within exercises over time, and the group by time interactions were analyzed with repeated measures ANOVA. Differences in training intensity between arms were analyzed with paired t-tests.

RESULTS

Baseline Characteristics of the Residents

The only variable that was statistically different between groups was age (see Table 4.1). Most residents in the control group were moderately cognitively impaired (<20 MMSE), while residents in the exercise group ranged from cognitively intact to severely cognitively impaired (<10 MMSE). The exercise group included two of the lowest scores, 5 and 8. Consideration should be given to the difference in length of stay between groups as the exercise group was at Deer Lodge nearly twice as long.

Table 4.1 Residents' Baseline Characteristics

Variable	Exercise Group	Control Group	T-test Significance[p]
N	8	7	
Female	1	3	
Age (years)	76.5±8.26 (68-90)	85.83±4.67 (79-90)	0.03*
Height (cm)	175.1±8.8	169.3±10.9	0.29
Body Mass (kg)	72.4±11.3	70.7±12	0.79
MMSE	18.71±8.56 (5-27)	13.75±4.79 (8-19)	0.32
Length of Stay (months)	12.75±7.85	6.60±4.34	0.14
Medications (No.)	5.86±2.95 (2-11)	5.20±3.27 (2-9)	0.71

Note. Values represent X± SD, except (x-x) which represents the range of results. [p] represents p-values, and * denotes statistically significant differences.

Resident Attendance and Adherence

The eight residents randomized into the exercise group attended 93% of the total strength training sessions (8 residents x 18 sessions). Four residents missed one session each, three residents missed two sessions each, and one resident had perfect attendance. The average number of missed sessions per resident was 1.25 out of 18.

Maximum Strength

At baseline, residents pulled (seated row) 19.25± 13.22kg, and pushed (bench press) 22.26± 9.16kg, when results from both arms were added. Residents pressed (leg press) 62.99± 27.64kg.

The exercise group gained more strength in the seated row during the intervention than the control group, as demonstrated by statistically significant effects of group, time, and the group by time interaction. In contrast, exercise and control groups were no different at pre- and post-tests and changed equally between test periods in the bench press exercise. This was revealed by a statistically significant effect of time. Leg press strength did not change for either group. Values of the maximum strength measures are presented in Table 4.2. Individual changes in bench press strength for the exercise and control groups are presented in Figure 4.1.

Table 4.2. Results of analysis on pre- and post-test maximum strength

Variables	Group	N	Pre-Test	Post -Test	ANOVA Group^p	Time^p	Interact^p
Bench Press Right (BPR)	Ex	7	10.91± 7.96	13.12± 8.71	0.441	0.018*	0.203
	Co	6	8.41± 5.76	9.17± 5.99			
Bench Press Left (BPL)	Ex	7	11.17± 7.17	12.66± 7.89	0.333	0.020*	0.752
	Co	6	7.54± 5.48	8.71± 6.04			
Seated Row Right (SRR)	Ex	7	13.47± 4.33	19.12± 4.57	0.020*	<0.001*	<0.001*
	Co	6	8.86± 5.90	8.94± 5.25			
Seated Row Left (SRL)	Ex	7	13.47± 4.22	18.64± 3.83	0.007*	<0.001*	<0.001*
	Co	6	7.92± 4.71	8.33± 4.54			
Leg Press (LP)	Ex	8	71.02± 33.4	74.15± 33.31	0.200	0.242	0.467
	Co	6	52.27± 13.1	53.03± 17.05			

Note. Ex and Co refer to exercise and control groups. Values for pre- and post-test are X± SD in kg. ^{p} represents the p-value and * denotes statistically significant findings.

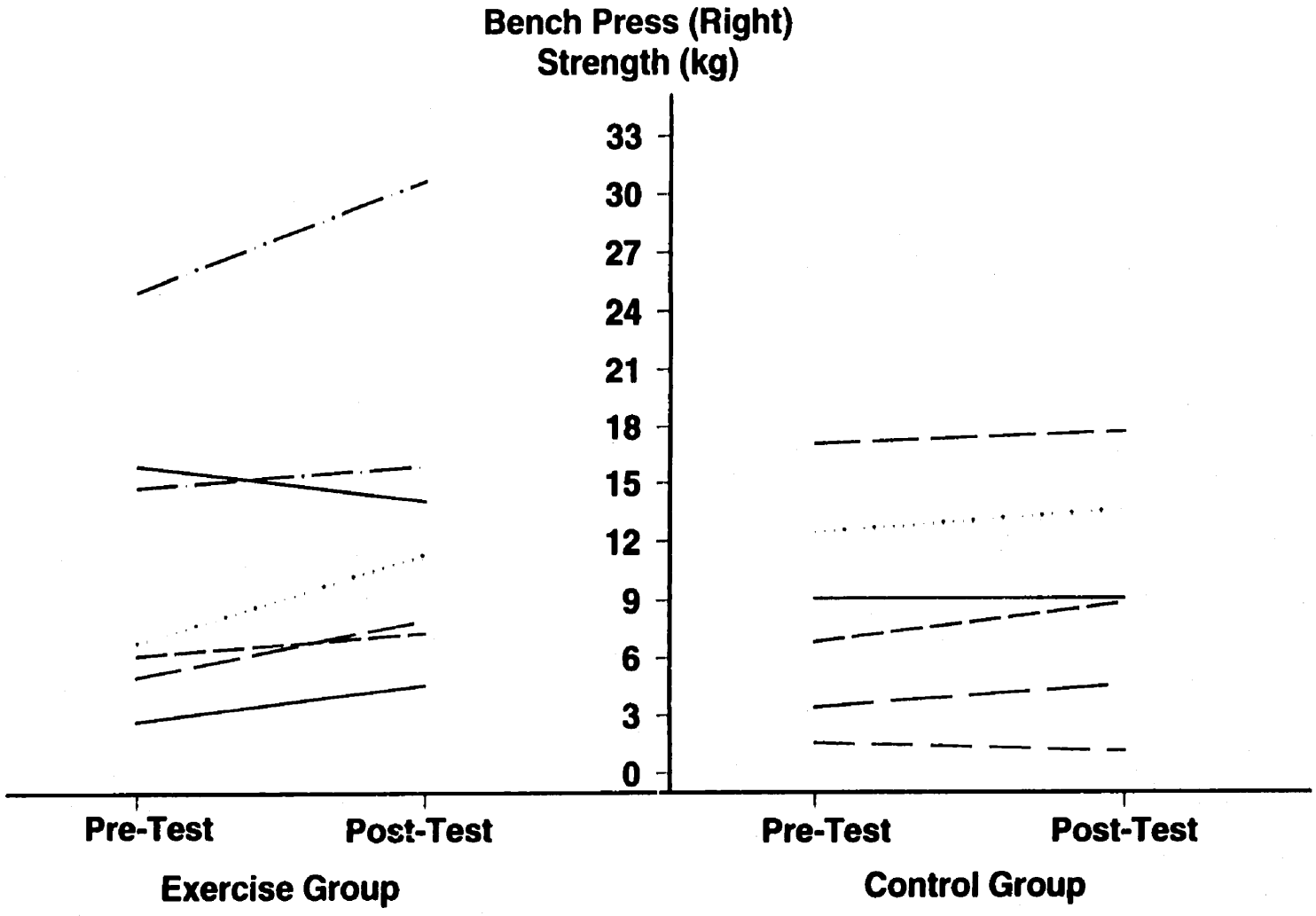

Figure 4.1 Individual changes in bench press right strength for exercise and control group members

Training Intensity

Training intensity was reported as the average intensity of both arms because the right and left arm training intensities were not significantly different ($p= 0.381$ and 0.356 for initial and final bench press values, and $p= 0.88$ and 0.170 for initial and final seated row values).

The initial training intensity for bench press and seated row was 44.38±16.76% and 73.02±13.49% respectively, whereas the final training intensity was 61.30±15.47% and 85.60±10.91%. Statistical analysis revealed a statistically significant effect of exercise ($p=0.012$) and time ($p=0.006$), but no interaction. This indicated that training intensity was consistently higher for seated row, and that both exercises had a similar increase in training intensity over the course of the intervention. These results are presented graphically in Figure 4.2.

Training Volume

The rate of increase in peak volume per week for bench press and seated row was discrepant (Figure 4.3). For seated row, peak volumes from week three to week five were significantly greater than the peak volume in week one. In week six the peak volume became significantly greater than the peak volume in week three. For bench press, only the peak volume in week six was significantly different from the peak volume in week one. Peak volumes per week for seated row and bench press became significantly different in week 4.

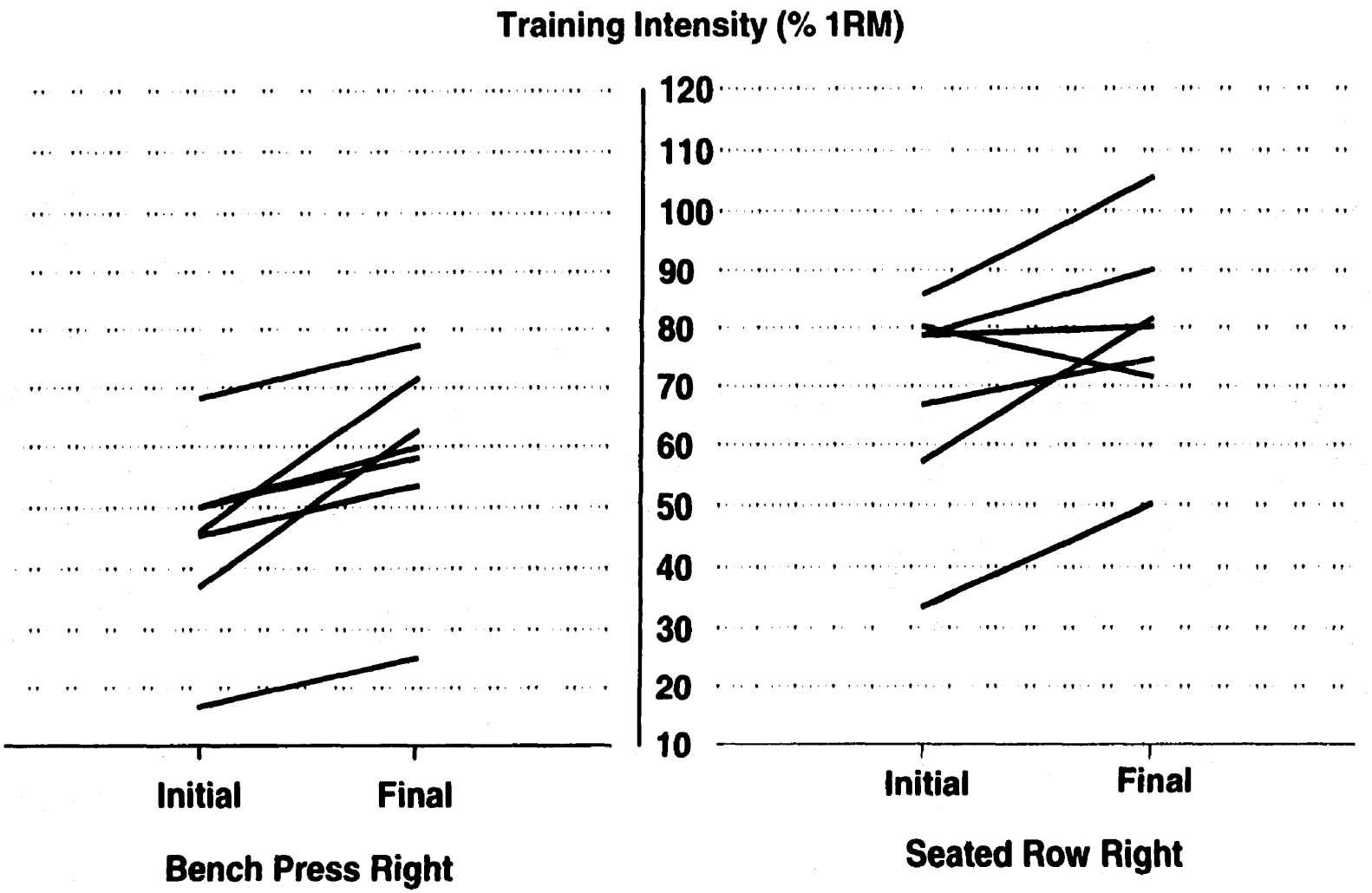

Figure 4.2. Residents' initial and final training intensities for bench press and seated row

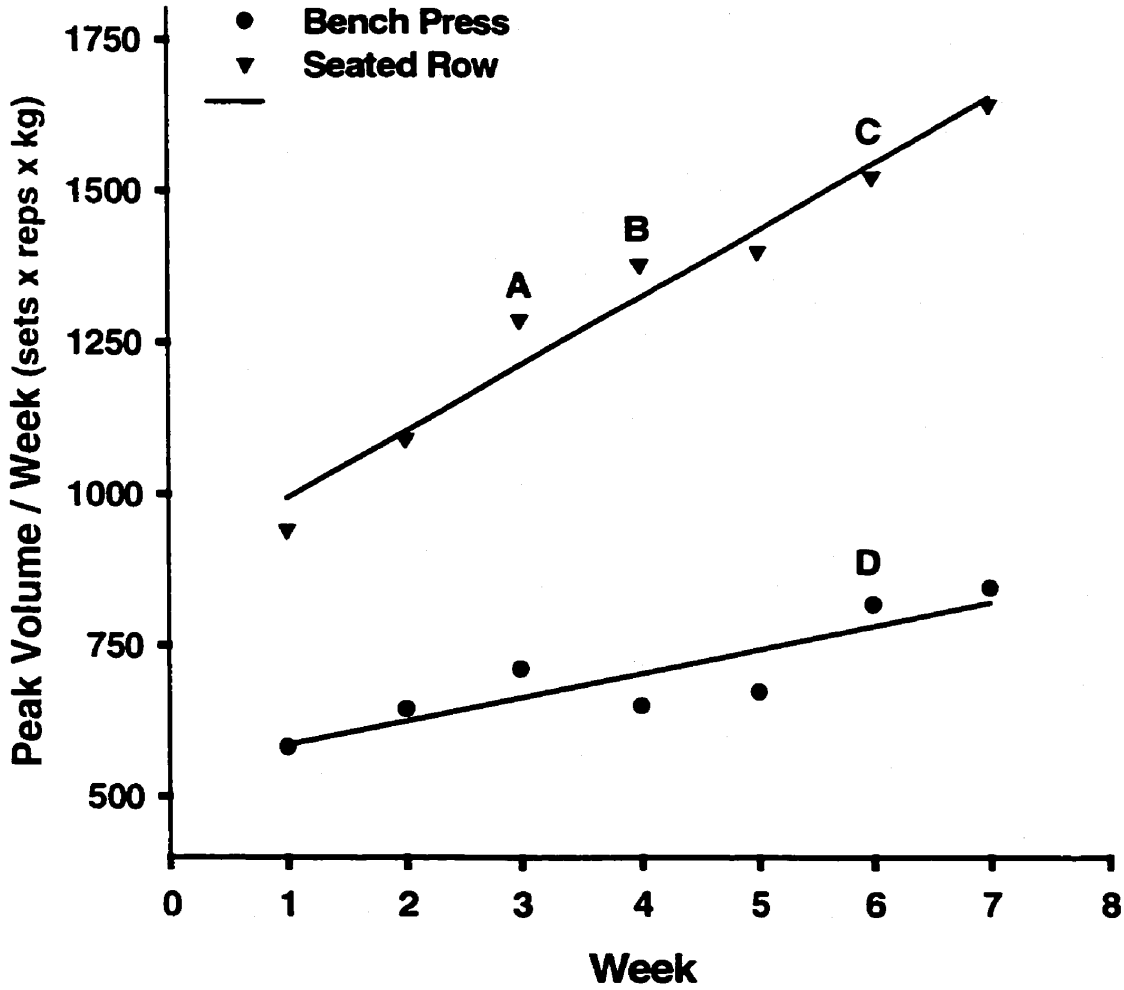

Figure 4.3 Linear representation of the rate of increase in peak volume per week for bench press and seated row.

Note. A indicates a significant difference from week one; B indicates a significant difference between exercises; C indicates a significant difference from week three; D indicates a significant difference from week one.

Chair Rise Performance

Maximum and self-paced chair rise performance did not change significantly from pre- to post-test (Table 4.3). Individual changes in self-paced chair rise performance for members of the exercise and control groups are presented in Figure 4.4. The mean self-paced chair rise performance time at pre-test was 2.73± 1.84 seconds.

Only 8 residents were able to rise without arm use from a typical Deer Lodge dining room chair (used in the self-paced protocol), and only 7 residents were able to perform the maximum chair rise protocol.

Pre-test maximum and self-paced chair rise time were not correlated to any pre-test strength variable or age following Bonferroni correction. R-values for age ranged from -0.791 to 0.475).

Table 4.3. Maximum and Self-paced Chair Rise Performance Times

Variable	Group	N	Pre-Test	Post-Test	ANOVA Group^p	Time^p	Interact^p
Maximum	Ex	3	1.30± 0.04	1.02± 0.08	0.430	0.490	0.188
	Co	4	1.69± 1.19	1.75± 1.06			
Self-paced	Ex	7	3.07± 2.27	3.13± 2.14	0.697	0.371	0.476
	Co	6	2.47± 0.98	2.96± 1.54			

Note. Ex an Co represent experimental and control groups. Values at pre- and post-test are X± SD in seconds. ^{p} represents the p-value.

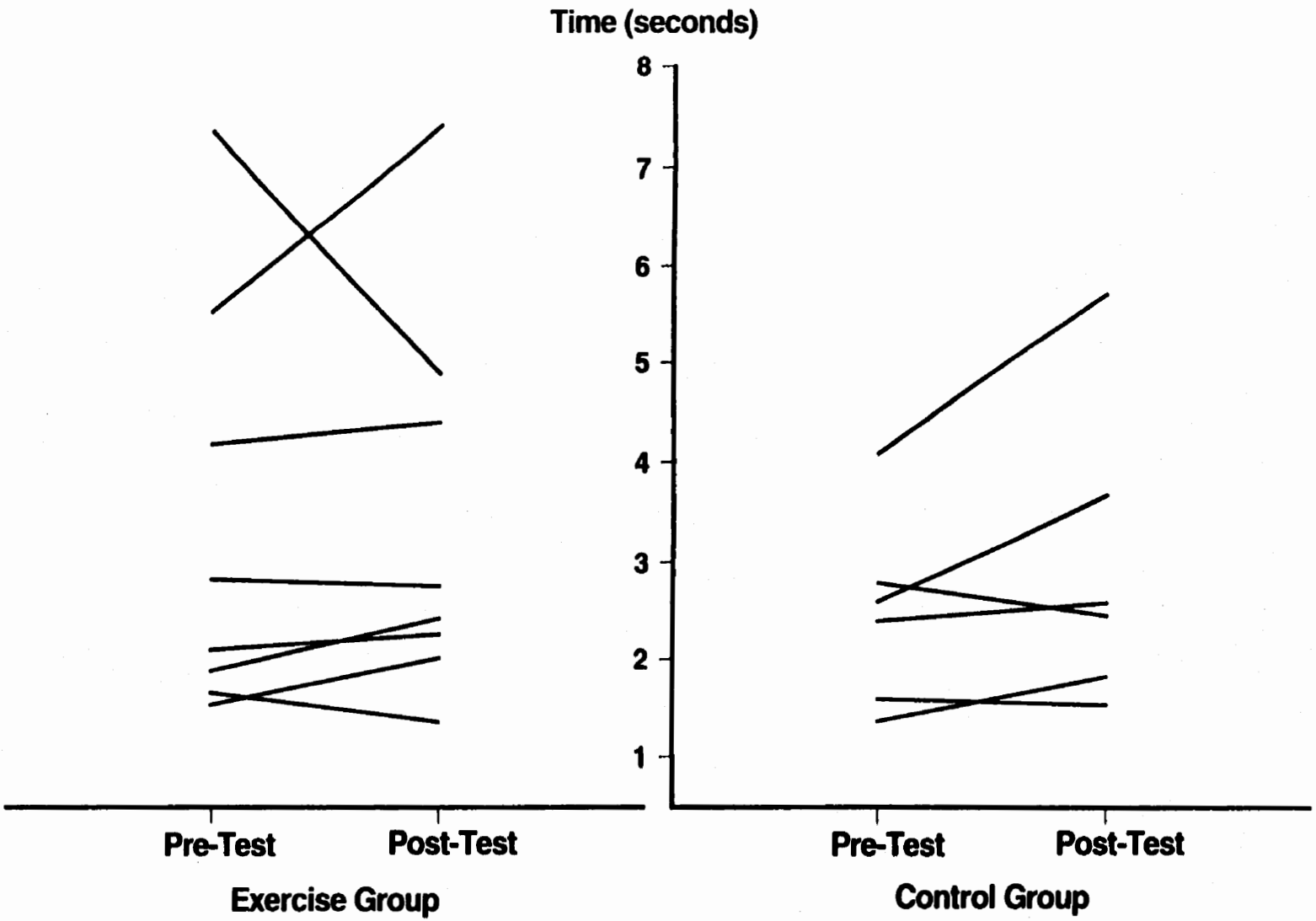

Figure 4.4 Self-paced chair rise performance times of exercise and control group members

DISCUSSION

The purpose of this study was to examine the effect of upper body strength training on the chair rise performance of institutionalized older adults. Two hypotheses were developed a priori. The first hypothesis was that strength training would increase maximum strength, and contingent upon this, the second hypothesis was that improved maximum strength would translate into reduced chair rise performance times. Results from this study partially supported the first hypothesis, but not the second hypothesis. A discussion of theoretical considerations, population characteristics, training variables, and the translation between strength and chair rise performance time will follow.

Theoretical Considerations

Two theoretical models were presented in the review of literature (Figures 1.1 and 1.2). One model presented a framework for the disablement process, the other illustrated the integrated components of physical function. While both models demonstrate how components of physical function relate to each other, the disablement model was chosen to guide the present study because it also presents components in a way that is amenable to intervention. According to this model, reversing any component (pathology, impairment, and functional limitations) will restore the subsequent consequences. For example, the goal of the present study was to reduce functional limitation in chair rise performance by reversing impairment with increased upper body strength. While reduction of functional limitation has implications in terms of disability, this relationship was not explored.

One of the limitations of the model by Verbrugge and Jette (1994) was that it did not consider the influence of psychosocial factors, the most relevant of which was likely motivation. As a result of the exclusion of these factors from the model, they were not measured in the present study. This is an important consideration because motivation could have influenced testing and training. Testing involved 1RMs, the most weight that can be lifted once. These tests are highly dependent on voluntary fatigue, a condition that is influenced by motivation. If residents were unmotivated, 1RM values would have been underestimated, and furthermore, a true 1RM is a test performed with maximal motivation. The influence of motivation on the present study may have been even greater as external motivation was not provided pre-testing. It is easier to control for motivation when it is not given, than to attempt to deliver consistent verbal encouragement. And despite residents' thorough medical screening, there was a common desire amongst research assistants not to push residents too far.

Population Characteristics

Physiological capacity and physical performance.

In keeping with the model of Schwartz (p. 10), we had planned to include only those individuals with low to mid normal (ie., region A to mid B in the model) physical performance capacity in the present study. Results from the present study suggest that the fifteen residents who participated were not in the expected regions, and therefore, did not have as much theoretical potential for improvement..

When compared to other studies with community dwelling older adults that measured 1RM strength on similar exercises, residents from the present study were only stronger

than 17 community dwelling elderly women, an average age of 67± 1.2 years old, who pushed (on the bench press) an average of 14.7± 0.9kg (Hunter *et al.*, 1995). When compared to institutionalized older adults, residents in the present study could leg press much more than those in the study by Fiatarone *et al.* (1993), and they had more upper body strength than participants in the study by Mihalko and McAuley (1996).

A greater understanding of residents' physical abilities was gained when they were compared to the self-paced chair rise performance times of other studies. Young adults and healthy community dwelling older adults could rise in 1.5 seconds, which was nearly half the time required by residents in the present study. And, functionally limited older adults took from an average of 3.8±4.0 seconds (Alexander et al., 2000) up to an average of 6.0±5.4 seconds with an upper limit of 26.7 seconds (Mourey et al., 2000).

The problem with the model presented by Schwartz was that it was mostly theoretical. The only research he had to support the model only defined the "toe", or low region of the curve (Fiatarone et al., 1993). Without definitions or descriptors for high physiological capacity or physical performance, or other support for the shape of the model, estimation of residents' position in the model was tenuous. However, residents in the present study were much stronger than those in the toe region, and residents' chair rise performance times were closer to those of young adults than those of functionally limited older adults. As a result, residents from the present study appeared to be positioned in the upper B region of the curve, where the ability to demonstrate improved chair rise performance from increased strength was restricted.

Attempting to position residents based on maximum chair rise performance times was inappropriate because only 8 of the 15 residents could complete the test. This

comparison would not have represented the sample of residents as a whole.

A limitation of the comparisons of residents to other studies is that none of the other studies reported both relevant strength measurements and chair rise performance times. Because the comparisons were made to studies reporting either strength measurements or chair rise performance times, residents' position in the model may be distorted.

Factors contributing to sample selection.

At least two factors contributed to the selection of a higher functioning sample of residents. First, the inclusion/exclusion criteria were quite restrictive, with only 21% of the total residents being eligible to participate. Results from this study did not elucidate how many residents were restricted by each criterion, as the decision to include/exclude residents was done by the Unit Coordinators. This information would be useful in determining how representative the residents who participated were to other institutionalized older adults (e.g., more or less cognitively impaired, etc.). In addition, this information may be beneficial for predicting the number of participants available to undertake research interventions. Predictions could be made if the inclusion/exclusion criteria related to the reasons why people were being institutionalized. For instance, if many residents were excluded due to cognitive impairment, and the number of people admitted to long-term care due to cognitive impairment was on the rise, then the number of participants available for research interventions may decline.

The second factor contributing to the selection of higher functioning residents was use of commercial weight training equipment. Two residents were excluded from the study because they were unable to transfer into the equipment safely. This equipment is

difficult for people with disability to access, creating unsafe conditions for residents and anyone assisting with the transfers. The mobility requirements imposed by commercial weight training equipment also restricted participation because researchers were only able to include residents with the ability to stand briefly. Without this requirement, residents would not have been able to attempt a transfer. While it is clear that the use of commercial weight training equipment contributed to the inclusion of higher functioning residents, the degree to which it contributed remains unclear.

Influence of an older control group.

The older control group did not confound the results of this study. The control group served to eliminate the influence of any systematic method error during testing, natural changes in strength or physical performance over time, and the effect of individual attention given to those involved in strength training. This was accomplished by using the control group as a reference to which the experimental group was compared. The influence of the aforementioned factors on strength or chair rise performance time are a minimal influence over 7 weeks. Because strength and chair rise performance are unlikely influenced by age-related changes in 7 weeks, the control group was an appropriate reference group. Furthermore, any group difference that might arise from having an older control group was irrelevant to the present study because the purpose was to examine change over time. This type of change is represented statistically as an interaction and is analyzed separately from main effects of group.

Having one group significantly older is interesting because it occurred despite randomization. Random assignment is supposed to distribute participants evenly to both

group, but with small sample sizes, the opportunity to evenly distribute participants decreases.

Performance of residents with severe cognitive impairment.

The two most cognitively impaired residents (MMSE's of 5 and 8) in the strength training group were the only residents who were excluded from portions of data analysis. Pre-test bench press strength was not measured for one of the two residents. This resident was unable to perform the exercise with a consistent range of motion and bilateral symmetry at pre-test. He was not immediately excluded from the study because his performance on other components of the study was satisfactory. The other resident excluded from analysis experienced what appeared to be paranoia, severe confusion and disorientation at the time of post-testing. As a result he was unable complete his test of seated row strength.

These two cases suggest that despite having the ability to follow "simple instructions", strength training interventions may not be feasible for residents with severe cognitive impairment (MMSE<10) due to inconsistent behavior. This is similar to a study that examined the reliability of chair rise performances among participants with Alzheimer's disease who had an average MMSE score of 9 (Tappen *et al.*, 1997). These authors reported an intra-class correlation coefficient of -0.04, the lowest reported reliability in the literature. Together, these results suggest that research with people who have low MMSE scores, (likely attributable to Dementia), require special considerations when involved in research that requires repeated testing. Two such considerations are an

increased sample size to compensate for variability in performance, and repeated testing to determine "typical" behavior.

Factors that Account for Strength Changes

The a priori hypothesis regarding changes in strength was that maximum strength would increase in the group who had undergone strength training. This hypothesis was partially supported as the training group increased strength in the seated row, but not bench press. Increasing strength in one exercise and not the other is uncommon and warrants further discussion. Explanations for this finding are discussed more fully in the following sections on training intensity and training volume. In contrast to our study, other upper body strength training intervention studies conducted with older adults using similar exercises and the same muscle groups have demonstrated strength increases in all exercises (Campbell *et al.*, 1999; Jozsi *et al.*, 1999; Taaffe *et al.*, 1999; Mihalko and McAuley, 1996; Hunter *et al.*, 1995; Taaffe *et al.*, 1995)].

The non-significant change in bench press strength may be questioned due to the small sample size. However, examination of individual changes in bench press strength revealed that both exercise and control groups experienced an increase in strength (Figure 4.1). The lack of dissociation between groups in strength gains supported the non-significant statistical results as this clearly illustrated that no interaction occurred.

Pre- and post-test measurements of leg press strength were included in the study to provide an indication of whether residents were benefiting from unmonitored use of their legs. Residents could have artificially improved chair rise performance from transfers into and out of the strength training equipment, or by practicing chair rise performance on

their own. The non-significant change in leg press strength indicates that residents did not substantially change daily leg use. Results from the chair rise performance tests could therefore be attributed to participation in the strength training intervention.

Training intensity.

The non-significant change in bench press strength may be explained by the residents' inability to train at a sufficient intensity (Figure 4.2). For the bench press, residents began at a low training intensity (mean 44.4%) and barely attained a moderate intensity by the end of the study (mean 61.3%). Conversely, for the seated row, residents began training at a moderate intensity (mean 73.02%) and approached a high intensity by the end of the study (mean 85.6% 1RM). Training intensities of 10 RM or 70% of maximum strength and heavier are associated with increased strength, even for older adults (for a detailed review see Kraemer *et al.*, 1996; or Porter *et al.*, 1995).

Length of intervention.

Despite training at a low intensity on the bench press, research suggests that changes in strength may have become apparent if residents trained longer than 7 weeks. Two studies have produced significant strength gains with low training intensities (less than 50% 1RM) (Hunter *et al.*, 1995; and Taaffe *et al.*, 1995). A distinguishing feature of these studies is that they were twice as long as the present study, 15 and 16 weeks long, respectively. This suggests that training at low intensity for longer periods of time would produce strength gains.

Other studies reporting strength gains in chest and back exercises involved high

intensity training, and were 10 weeks or longer (Campbell *et al.*, 1999; Jozsi *et al.*, 1999; Taaffe *et al.*, 1999; Hunter *et al.*, 1995; and Taaffe *et al.*, 1995).

Training volume.

The rate of increase in peak volume per week was greater for the seated row than the bench press (Figure 3). This indicated that residents were able to lift more weight more quickly on the seated row. As mentioned in the methods, training volume was the product of the number of sets, repetitions and training load. Because the first two variables in the training volume equation were fixed (i.e., always 3 sets of 8 repetitions), increases in volume were a reflection of the increased load. The increased rate in peak volume per week of seated row demonstrated that residents were getting stronger over the length of the intervention and therefore explained why residents were stronger in the seated row at post-test.

Intensity and load on the seated row.

Researchers involved in the present study are unable to explain why residents could not train at a higher intensity or load on the bench press because the study was not designed to answer this question. However, two speculative explanations are presented in the following section.

First, inability to train at a high intensity or load on the bench press may be attributable to muscle characteristics. Numerous studies have demonstrated variability in fiber type proportion between muscles (Houmard *et al.*, 1998; Lexell *et al.*, 1994; Grimby *et al.*, 1982; Johnson *et al.*, 1973; and Jennekens *et al.*, 1971). Although no significant

difference was found in the proportion of type I fibers of latissimus dorsi or pectorialis major muscles, there was a difference between latissimus dorsi (50.5% type I) and triceps (32.6%) (Johnson *et al.*, 1973). The latter comparison is relevant because residents in the present study were instructed to perform the bench with a "narrow" grip. This type of arm movement places more stress on the triceps than a "wide grip". It is widely accepted that muscles with a higher proportion of type II fibers (i.e. triceps) fatigue more quickly than muscles with a higher proportion of type I fibers, like the latissimus dorsi (Vander *et al.*, 1994). Residents' inability to train at a high intensity or load over 3 sets of 8 repetitions may therefore be attributable to a greater prevalence of fatigable (type II) fibers in a primary muscle group. Residents may have been able to train at a comparable intensity or load on the bench press if they were to have performed four or six repetitions.

Second, the increased rate of peak load per week of seated row may have been a result of residents' and/or research assistants' perceived comfort with this exercise. Research assistants were instructed to increase load after three sets of eight repetitions if they were performed properly. However, no definition of proper performance other than completing the 3 sets of 8 repetitions was set a priori. This meant that other than performing 3 sets of 8 repetitions, successful completion of an exercise was open to interpretation by both resident and research assistant. For example, despite completing 3 sets of 8 repetitions, a resident may not believe that their performance was proper because they experienced too much discomfort. Similarly, a research assistant may believe that a resident's performance included too many repetitions that were not smooth or of an insufficient range of motion. As proper completion of the exercises requires agreement between resident and research assistant, systematic disagreement over proper

completion of the bench press exercise may be responsible for the dissimilar rate of peak loading per week. While being subjective, most residents indicated that they felt more comfortable performing the seated row, and most research assistants also stated that they felt more comfortable performing the seated row after training on the equipment themselves. Again, it remains unclear from this research whether the residents' or research assistants' perceptions of proper completion of the bench press did influence the rate of peak loading, but it is a possibility.

Transition from Limitation to Functional Impairment

Chair rise performance.

The second hypothesis specified that chair rise performance time would decrease from pre- to post-test following strength training. Results from this study do not support the second hypothesis, as maximum and self-paced chair rise performance did not change significantly.

This hypothesis was developed to test the effect of reduced impairment on functional limitation in the disablement model presented by Verbrugge and Jette (1994). In the present study, reduction of impairment was supposed to be achieved with upper body strength training. However, as previously discussed, upper body strength was only increased in one exercise, which only partially satisfied the first hypothesis. Without having completely fulfilled the goal of reducing impairment, the model predicted that functional limitation would continue.

Although this successful prediction appeared to support the model and the effect of impairment on functional limitation, in reality, the results were inconclusive. Scientific

testing requires that the null hypothesis be disproved before the alternative hypothesis can be accepted. The null hypothesis was that increased upper body strength would not reduce chair rise performance time. Without successfully increasing upper body strength the null hypothesis could not be rejected, and the effect of impairment on functional limitation remained untested.

Because upper body strength partially increased, one could argue that the null hypothesis could have been disproved. However, the term upper body strength, which was developed a priori to the study, may be misleading. In reality, bench press was considered the most important exercise for reducing functional limitation, as it has a stronger theoretical association to chair rise performance than seated row. The theory of specificity of training purports that the more specific training is to a physical task, the greater the influence training will have (Baechle, 2000). Training should be specific to the muscle groups activated during the physical task, the type(s) of muscular contraction required, joint angles, and the speed/velocity of the muscle contraction (Kraemer *et al.*, 1998). While bench press may not be as specific to the joint angles involved in rising from a chair as a seated dip, it was expected to contribute to residents' chair rise performance because it involved similar muscle groups and muscular contractions.

Due to the strong association between bench press and chair rise performance, if bench press strength had increased, discussion of the relationship of upper body strength and functional limitation would have been appropriate.

Importance of other attributes.

According to the model by Schwartz (1997), it was theoretically possible for residents in the present study to improve chair rise performance with additional strength. However, this connection of strength and chair rise performance was made while only considering one explanatory variable. As mentioned in the review of literature, many physical attributes contribute to chair rise performance. It is possible that other factors contributed, independently or by interaction, to difficulty in chair rise performance. An attribute commonly associated with older adults' difficulty in chair rise performance is balance (Mourney, *et al.*, 2000; Hughes *et al.*, 1996; and Schultz *et al.*, 1992). Impairment in balance may have increased the difficulty of rising from a chair, or reduced the ability to exert strength. In addition to physical attributes one could also examine the influence of various co-morbidities.

Sample size.

Although the non-significant changes in chair rise performance times may be questioned based on the small sample size, no clear trend was established in the exercise or control groups when individual results were examined (Figure 4.4). These results could be explained by poor reliability of the chair rise performance tests or by inconsistent behavior on the part of the residents.

Conclusion

Previous research had identified very frail older adults as those who might improve their chair rise performance with strength training. Institutionalized older adults who participated in the present study did not have as much theoretical potential to improve in chair rise performance as initially anticipated. The inclusion of more physically able residents was due to restrictive inclusion and exclusion criteria, and to the use of strength training machines. This sample included those with severe cognitive impairment who could follow "simple instructions", but they were unable to complete the requirements of the intervention.

Despite identical strength training protocols, the 7 week strength training intervention only succeeded at increasing strength in the seated row. The increase in seated row alone was attributed to residents' ability to train at a moderate to high intensities and with increasing loads on this exercise. The present study was unable to determine why residents could lift more on the seated row than on the bench press. This may be due to the length of the intervention, differences in muscle characteristics, or systematic disagreement between residents' and research assistants' perception of proper exercise performance.

Without increased bench press strength, non-significant chair rise performance times were expected, but the relationship of strength to chair rise performance was inconclusive. Other variables that might influence chair rise performance times, such as balance, were not considered in the present study.

Recommendations

1. In future studies where the effects of strength on functional limitation is of interest, only people with functional limitation in the observed task(s) should be included, or participants should be blocked into groups based on similar amounts of functional limitation for analysis.
2. In future studies where the goal is to restore functional limitation, equipment that accommodates people with severe ambulatory limitations and/or the inability to rise from a chair should be selected.
3. In future studies that include people with severe cognitive impairment, multiple tests should be performed to discern typical behavior/performance.
4. In future studies where the goal is to increase strength in frail older adults, a specific training intensity should be established, rather than the number of repetitions.

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