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THE EFFECTS OF STRENGTH TRAINING ON STRENGTH, MOBILITY AND BALANCE IN TWO GROUPS OF INSTITUTIONALIZED ELDERLY SUBJECTS

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A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfilment of the requirements for the degree of Master of Science in Rehabilitation Science

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ABSTRACT

The purpose of this study was to determine the timing and extent of gains in strength, mobility, balance and functional status that follow a high-intensity strengthening program offered to two groups of institutionalized elderly subjects. Thirty two subjects were randomly selected and classified as a person with a HIGH or LOW mobility based on the timed “Up and Go” (TUG) score (<20 sec or ≥ 20 sec respectively). The hypothesis was that the exercise regimen would have a greater impact on the LOW mobility group as compared to the HIGH mobility group. Dynamic strength, mobility, balance and functional level were evaluated by the one repetition maximum (1RM), TUG and average walking speed, Berg balance scale and the Physiotherapy Clinical Outcomes Variables (COVS) respectively. Following the 12 week intervention, strength increased in both the LOW and HIGH mobility group (121% and 81% respectively; p<0.05), whereas balance improved only in the LOW mobility group (49%, p<0.05). The mobility and functional level of the subjects did not change in either group. In conclusion, the high-intensity strength training was found to have a larger impact on the strength and balance of the LOW mobility group. However, in view of the small sample size and the presence of comorbidity the 12 week program failed to bring about gains in mobility or function.
RÉSUMÉ

Le but de cette étude était de déterminer l'évolution dans le temps des gains de force musculaire, mobilité, équilibre et statut fonctionnel, suite à un programme de renforcement musculaire intensif offert à deux groupes de personnes âgées vivant en institution. Trente deux sujets ont été sélectionnés aléatoirement et classifiés en deux groupes en fonction de leur mobilité, telle que déterminée par le "timed Up and Go" (TUG), soit un groupe à FAIBLE mobilité (≥20 sec) ou un groupe avec BONNE mobilité (<20 sec). L'hypothèse était que le programme d'exercice aurait un plus grand effet sur le groupe à FAIBLE mobilité que sur le groupe avec BONNE mobilité. La force dynamique, la mobilité, l'équilibre et le niveau fonctionnel ont été évalués par une répétition maximum (1RM), le TUG et la vitesse moyenne de marche, le "Berg balance scale" et le "Physiotherapy Clinical Outcomes Variables" (COVS) respectivement. Suite aux 12 semaines du programme, la force musculaire augmenta dans les deux groupes (121% et 81% pour les groupes FAIBLES et BONS, respectivement, p<0.05), tandis que l'équilibre augmenta seulement dans le groupe à FAIBLE mobilité (49%, p<0.05). La mobilité et le niveau fonctionnel n'ont pas changé ni dans l'un ni dans l'autre des groupes. En conclusion, le programme de renforcement intensif a eu un plus grand effet sur la force musculaire et l'équilibre du groupe à FAIBLE mobilité. Cependant, le programme de 12 semaines n'a pas réussi à apporter de gains de mobilité ou de fonction, possiblement à cause de la présence d'un haut niveau de comorbidité et du petit nombre de sujets.
ACKNOWLEDGMENTS

I would first like to thank all the veterans of Ste-Anne's Hospital who willingly volunteered to participate in this research study. Without their cooperation this project would not have been possible.

Secondly, I express gratitude to the Physiotherapy staff, especially Mme Michelle Rousseau, Guylaine Cote, Michelle Lamare, Nicole Levesque and Judith Martin who helped in the implementation of this exercise program. I would also wish to thank Debby Knuutila who conducted the monthly evaluations. This work could not have been successful without their invaluable help, cooperation and support.

I owe a special debt to my supervisors, Dr. Diane St-Pierre and Judi Newnham who supported me through this long process whether it was assistance in the everyday running of the exercise program or feedback on this paper.
Many thanks are also extended to the nursing staff of Ste-Anne’s Hospital. They were, at all times, helpful and cooperative. Their assistance in the recruitment of study subjects is much appreciated.

My warmest thanks are extended to my family and my close friends. Their love, understanding and confidence in my abilities kept me going during my studies. You were always there for me.
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1RM: One repetition maximum
ADL: Activities of daily living
ANOVA: Analysis of variance
Berg: Berg balance scale
BMI: Body mass index
COVS: Physiotherapy clinical outcomes variables
CSA: Cross sectional area
deg: Degrees
GDS: Geriatric depression scale
HSRF: Health status rating form
ICC: Intraclass correlation coefficient
Kenny: Kenny self care evaluation index
Kg: Kilogram
m: Meters
PDI: Physical disability index
ROM: Range of motion
sec: Seconds
TUG: Timed Up and Go test
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INTRODUCTION

Declines in muscle strength in older individuals are often ignored until weakness prevents the performance of the various activities of daily living (ADL) or contributes to a fall. Strategies that improve the level of day to day activity of elderly people are important in view of the fact that customary activity is an independent determinant of hip fractures in the elderly (Coupland et al, 1993). Indeed, muscle weakness, impaired gait and balance are known to be among the primary risk factors for falls in the elderly (Aniansson et al, 1984b; Gehlsen and Whaley, 1990; Rubenstein et al, 1990; Whipple et al, 1987). Although these parameters have multiple causes, physical activity may play a role in their management (Aniansson et al, 1984a; Barry and Eathorne, 1994; Buchner et al, 1993; Fiatarone and Evans, 1993b; Judge et al, 1993; McMurdo et al, 1997; Mulrow et al, 1993; Province et al, 1995).

Most studies to date have focused on the effects of exercise on strength and endurance in community dwelling elderly individuals, and little is known about the benefits of exercise in people living in long-term care facilities.
This population is particularly important in view of their higher incidence of falls and functional dependence in comparison to those living in the community (Clark et al, 1993). Furthermore, previous studies tended to focus on a selective mobility-impaired population, excluding patients with a history of stroke or Parkinson's disease (Cress et al, 1991; Fiatarone et al, 1994; Frontera et al, 1988; Judge et al, 1993, 1994; Sipila and Suominen, 1995). Therefore, we need to determine the impact of strength training on a broader range of people with mobility impairments.

Lastly, high-resistance training programs have the potential to reduce or delay the proportion of functional dependence and risk of falls that are associated with muscle weakness (Province et al, 1995). However, in a time of shortages in personnel and funding we need to know what type of patient population would benefit the most from exercise programs.

It was the intent of this study to determine the timing and extent of gains in strength, mobility, balance and functional status that follow a high-intensity strengthening program offered to institutionalized elderly subjects. The effects of an exercise regimen were compared between two groups of elderly
patients, namely a LOW and a HIGH mobility group, to evaluate whether the outcome of the training was influenced by the initial mobility level of the subjects. This was accomplished by recruiting 32 patients from a long term care in-patient facility. The subjects were randomly selected and classified as a person with a HIGH or LOW mobility based on the timed “Up and Go” (TUG) score (<20 sec or ≥ 20 sec respectively). Both groups trained three times per week for a period of 12 weeks. Dynamic strength, mobility and balance were evaluated every 4 weeks during the training period by the one repetition maximum (1RM), TUG, average walking speed and the Berg balance scale (Berg) respectively. Functional and psychological status were assessed by the Physiotherapy clinical outcomes variables (COVS) and the Geriatric depression scale (GDS) before and after the training period. By undertaking this type of clinical study, it may be determined whether gains in knee extension strength in an institutionalized elderly population lead to improvements in mobility, balance, functional ability and psychological status. Furthermore, the impact of a high-intensity strengthening program on a LOW and a HIGH mobility group can be compared.
CHAPTER 1

LITERATURE REVIEW

1.1 Age-related Changes in Muscle Function

With increasing age the human skeletal muscle undergoes both structural and functional changes, the most striking of which are the reduction in muscle volume and muscle strength (Grimby and Saltin, 1983; Munset, 1984; Vandervoort et al, 1986). Cross-sectional studies have investigated a variety of limb muscles in groups of young, middle-aged and old adults. Voluntary strength was reported to increase up to the third decade, remain constant to the fifth decade and then demonstrate an apparent decline after the age of about 60 (Aniansson et al, 1983; Danneskiold-Samsoe et al, 1984; Larsson et al, 1979; Vandervoort, 1992). The reduction of muscle strength with age has been described in several studies, usually with isometric (static) measurements. A sample of cross-sectional studies involving isometric testing of various muscle groups is presented in Table 1.
TABLE 1
Voluntary Isometric Strength of Elderly Men and Women Compared to Young Adults

<table>
<thead>
<tr>
<th>Muscle group</th>
<th>Sex</th>
<th>Age of elderly subjects (decade)</th>
<th>% of young adult</th>
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<tbody>
<tr>
<td><strong>Knee extensors</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Johnson (1982)</td>
<td>F</td>
<td>6-9</td>
<td>60</td>
</tr>
<tr>
<td>Larsson et al (1979)</td>
<td>M</td>
<td>7</td>
<td>75</td>
</tr>
<tr>
<td>Murray et al (1985)</td>
<td>F</td>
<td>8-9</td>
<td>63</td>
</tr>
<tr>
<td>Young et al (1985)</td>
<td>M</td>
<td>8</td>
<td>61</td>
</tr>
<tr>
<td><strong>Ankle plantarflexors</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Davies et al (1986)</td>
<td>M/F</td>
<td>7-8</td>
<td>62/72</td>
</tr>
<tr>
<td>McDonagh &amp; Davies (1984)</td>
<td>M</td>
<td>7-8</td>
<td>59</td>
</tr>
<tr>
<td></td>
<td>M/F</td>
<td>8</td>
<td>71/83</td>
</tr>
<tr>
<td><strong>Ankle dorsiflexors</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vandervoort &amp; McComas (1986)</td>
<td>M/F</td>
<td>9-10</td>
<td>56-63</td>
</tr>
<tr>
<td></td>
<td>M/F</td>
<td>8</td>
<td>73/81</td>
</tr>
<tr>
<td><strong>Handgrip</strong></td>
<td></td>
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</tr>
<tr>
<td>Mathiowetz et al (1985)</td>
<td>M</td>
<td>8-10</td>
<td>47</td>
</tr>
<tr>
<td>Mathiowetz et al (1985)</td>
<td>F</td>
<td>8-10</td>
<td>41</td>
</tr>
<tr>
<td>Shephard (1969)</td>
<td>M</td>
<td>7</td>
<td>82</td>
</tr>
<tr>
<td><strong>Elbow flexors</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clarkson &amp; Dedrick (1988)</td>
<td>F</td>
<td>7-8</td>
<td>85</td>
</tr>
<tr>
<td>McDonagh &amp; Davies (1984)</td>
<td>M</td>
<td>7-8</td>
<td>80</td>
</tr>
</tbody>
</table>
Healthy people in the 7th and 8th decades score on average about 20-40% less during strength tests than young adults (Clarkson et al, 1981; Davies et al., 1986; Doherty et al., 1993b; Fisher and Birren, 1947; Kallman et al., 1990; Larsson et al., 1979; McDonagh and Davies, 1984; Petrella et al., 1989; Shephard, 1969; Young et al., 1985), and the very old (9th-10th decades) demonstrate even greater (35-45%) reductions in muscle strength (Kallman et al., 1990; Murray et al., 1980; Vandervoort and McComas, 1986). Similar age-related declines in muscle strength have been documented with females (Clarkson and Dedrick, 1988; Davies et al., 1986; Johnson, 1982; Mathiowetz et al., 1985; Murray et al., 1985; Vandervoort and McComas, 1986; Young et al., 1984). Therefore, although men and women differ in absolute levels of strength, the percentage decrement in old age is equivalent across the sexes (Roos et al., 1997; Vandervoort et al., 1986).

Concentrically (muscle shortening) measured muscle strength has also been reported to be lower in older age groups. Knee extensor muscle torques have been reported to be 25 to 30% lower in 60-69 year old and 35 to 45% lower
in 70-86 year old men and women, in comparison to young individuals (Refer to Table 2). Moreover, this weakness is more predominant when tested at fast \([180 \text{ degrees (deg)} / \text{seconds (sec)}]\) muscle contractions (Aniansson et al, 1986; Brooks and Faulkner, 1994; Laforest et al, 1990; Larsson et al, 1979; Overend et al, 1992; Poulin et al, 1992).

In contrast to the declines in concentrically and isometrically measured muscle strength, eccentrically (muscle lengthening) tested strength is better preserved (Brooks and Faulkner, 1994; Hortobagyi et al, 1995; Phillips et al, 1991; Poulin et al, 1992; Vandervoort et al, 1990). In fact, at fast velocities \((180 \text{ deg} / \text{sec})\), older men were reported to be equal to younger men in eccentric knee extension peak torque (Poulin et al, 1992). Similar observations have been made with lengthening contractions of old versus young mice (Brooks and Faulkner, 1994; Phillips et al, 1991). Higher content of connective tissue in old muscles may underlie this better preservation of eccentric strength (Overend et al, 1992; Rice et al, 1989).

This age associated decline in muscle strength has been mainly attributed to a loss of muscle mass (Frontera et al, 1991; Grimby, 1988; Overend et al, 1992;
# TABLE 2

Voluntary Concentric Strength of Elderly Men and Women Compared to Young Adults

<table>
<thead>
<tr>
<th>Muscle group</th>
<th>Sex</th>
<th>Age of elderly subjects (decade)</th>
<th>% of young adult</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Knee extensors</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Frontera et al (1991)</td>
<td>M/F</td>
<td>7-8</td>
<td>79</td>
</tr>
<tr>
<td>Harries &amp; Bassey (1990)</td>
<td>F</td>
<td>7</td>
<td>70</td>
</tr>
<tr>
<td>Johnson (1982)</td>
<td>F</td>
<td>6-9</td>
<td>60</td>
</tr>
<tr>
<td>Laforest et al (1990)</td>
<td>M/F</td>
<td>6-7</td>
<td>74</td>
</tr>
<tr>
<td>Larsson et al (1979)</td>
<td>M</td>
<td>7</td>
<td>75</td>
</tr>
<tr>
<td>Murray et al (1985)</td>
<td>F</td>
<td>8-9</td>
<td>60</td>
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<tr>
<td>Overend et al (1992)</td>
<td>M</td>
<td>7-8</td>
<td>70</td>
</tr>
<tr>
<td>Poulin et al (1992)</td>
<td>M</td>
<td>7-8</td>
<td>68</td>
</tr>
<tr>
<td>Stalberg et al (1989)</td>
<td>M/F</td>
<td>7-8</td>
<td>70/60</td>
</tr>
<tr>
<td><strong>Knee flexors</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Frontera et al (1991)</td>
<td>M/F</td>
<td>7-8</td>
<td>81</td>
</tr>
<tr>
<td>Laforest et al (1990)</td>
<td>M/F</td>
<td>6-7</td>
<td>82</td>
</tr>
<tr>
<td><strong>Ankle plantarflexors</strong></td>
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<td></td>
</tr>
<tr>
<td>Fugl Meyer et al (1980)</td>
<td>M/F</td>
<td>7</td>
<td>55/68</td>
</tr>
<tr>
<td><strong>Elbow extensors</strong></td>
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</tr>
<tr>
<td>Frontera et al (1991)</td>
<td>M/F</td>
<td>7-8</td>
<td>80</td>
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<tr>
<td>Poulin et al (1992)</td>
<td>M</td>
<td>7-8</td>
<td>69</td>
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<tr>
<td><strong>Elbow flexors</strong></td>
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<tr>
<td>Doherty et al (1993b)</td>
<td>M/F</td>
<td>7-9</td>
<td>71/69</td>
</tr>
<tr>
<td>Frontera et al (1991)</td>
<td>M/F</td>
<td>7-8</td>
<td>81</td>
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Reed et al, 1991). A decline of 33% in muscle mass has been reported to occur between 30 and 80 years of age (Tzankoff and Norris, 1977). This decline is closely related to the reduction in number of muscle fibers which has been confirmed in both human (Aniansson et al, 1986; Grimby et al, 1982; Larsson et al, 1979; Lexell et al, 1983; Sato et al, 1984) and animal species (Caccia et al, 1979; Hooper, 1981; Ihemelandu, 1973; Layman et al, 1980). The magnitude of the reduction in muscle fibers during adult life has been estimated to be around one third to a half (Lexell et al, 1983).

The etiology of muscle fiber loss is unclear, but possible mechanisms include irreparable damage of fibers or a permanent loss of contact between the nerves and the muscle fibers (Lexell et al, 1988). Indeed, electromyographical studies of aging human muscles have reported a reduction in the number of functioning motor units (Brown, 1972; Campbell et al, 1973; Doherty et al, 1993a; Sica et al, 1976; Vandervoort and McComas, 1986). Also, significantly fewer motor neurons have been found in the spinal cords of old individuals (Tomlinson and Irving, 1977). Similar observations have been reported in animal studies (Caccia et al, 1979; Edstrom & Larsson, 1987; Einsiedel & Luff, 1992a; Hashizume et al, 1987; Ishihara et al, 1987;
Kanda & Hashizume, 1989; Klitgaard et al, 1989; Larsson et al, 1991). This gradual loss of motoneurons has been reported to preferentially affect the largest and fastest conducting neurons which mainly innervate type II fibers (Aniansson et al, 1986; Larsson, 1983; Lexell et al, 1988). As a result, fiber type proportions becomes altered with age, giving a higher proportion of type I fibers (Larsson, 1983; Larsson et al, 1979).

Initially, the neuromuscular system is able to partially compensate for the gradual loss of motoneurons. The collected evidence implies that part of the fiber population undergoes a denervation and reinnervation process with increasing age, whereby some motoneurons have enlarged their own motor unit territory by sending collateral sprouts from surviving motor axons to denervated muscle fibers (Lexell et al, 1988; McCarter, 1990; Stalberg and Fawcett, 1982). Dramatic increase in the incidence of motoneurone sprouts has been reported both in human (Gutmann and Hanzlikova, 1976) and animal studies (Fagg et al, 1981). Accordingly, close examination of fiber type arrangement in aging muscles has revealed a significant increase in fiber type grouping (Essen Gustavsson and Borges, 1986; Grimby, 1988; Lexell et al, 1986; Oertel, 1986). The extent of sprouting, however seems to be limited
by the aging process (Einsiedel & Luff, 1992a, 1992b; Larsson et al, 1991; Pestronk et al, 1980). Furthermore, this innervation creates an extra burden on the remaining nerve cells and ultimately results in loss of muscle fibers as the number of viable motoneurons becomes critically reduced (Vandervoort et al, 1986). This loss of muscle fibers become permanent with muscle being replaced by fat and fibrous tissue (Borkan et al, 1983; Lexell et al, 1988; Rice et al, 1989).

A reduced mean fiber area, preferentially the type II fast-twitch glycolytic fibers, has frequently been reported, further contributing to the decline in muscle mass observed in aging muscles (Aniansson et al, 1986; Frontera et al, 1991; Grimby et al, 1982; Jennekens et al, 1971; Larsson, 1983; Larsson et al, 1979; Lexell and Downham, 1992; Lexell and Taylor, 1991; Lexell et al, 1988; Rice et al, 1989; Scelsi et al, 1980; Tomonaga, 1977). However, only minor changes in mean fiber size are reported until around the age of 80 (Aniansson et al, 1986; Grimby et al, 1982). This decrease in fiber area probably stems from changes in physical activity and fitness level that accompanies old age (Lexell and Taylor, 1991). Greater type II atrophy has been demonstrated in leg muscles as compared to arm muscles of elderly
subjects, presumably due to a decreasing use of the lower limbs in elderly groups (Grimby, 1988). Slow moving elderly people rarely produce rapid movements. It is, therefore, probable that type IIb motor units are seldom recruited in the lower extremity (McDonagh et al, 1984), thus leading to their atrophy. In contrast, more forceful arm contractions may produce sufficient recruitment of the high threshold motor units in the upper extremity to maintain the size of their muscle fibers (Grimby, 1988).

These age-related changes in muscle mass and subsequent decline in muscle strength renders a large number of elderly at or near 'thresholds' of physical ability, needing only minor intercurrent illness to compromise their present level of functional independence (Young, 1986). The practical implications of reduced muscle strength in the lower extremities can be reduced function in various daily activities, such as rising from a chair and crossing an intersection safely. These may become difficult for the elderly individual with increasing age (Grimby, 1986; Young, 1986). The person's quality of life and his ability to live independently may become compromised.
1.2 Age-related Changes in Mobility and Balance and Their Relationship to Muscle Strength

Mobility refers to "movement on one surface involving change of position or location" (Trombly, 1989). Independent mobility in frail elderly persons usually involves the ability to get in and out of a bed and chair, on and off a toilet, and walking a few meters. Mobility functions, such as rising from a chair (Ikeda et al, 1991), adequate walking speed (Judge et al, 1993) and managing stairs (Lundgren-Linquist et al, 1983) are also prerequisites to many other activities of daily living. High level of functioning of elderly persons is, therefore, reported to be dependent on an adequate mobility level (Hoxie & Rubenstein, 1994; Judge et al, 1993; Lerner-Frankiel et al, 1986). Very slow walkers are, in fact, usually home bound (Imms and Edholm, 1981).

The ability to accomplish these activities is easily taken for granted by healthy young adults, but is threatened in old age by the presence of various muscular and neurological impairments (Bassey et al, 1992). The incidence of mobility impairments in old adults is high (Rantanen et al, 1994; Schultz, 1992). Lair & Lefkowitz (1990) report that at least 56% of nursing home residents older
than 64 years need personal assistance in walking and 83% need personal assistance with one or more activities of daily living. For residents older than 84 years these numbers are even higher (69 and 92% respectively).

The locomotor behavior of older people is characterized by its low velocity (Ferrandez et al, 1990; Hageman and Blanke, 1986; Imms and Edholm, 1981; Murray et al, 1969). Normal gait requires adequate neuromuscular control, muscle strength, balance, as well as functioning lower extremity joints. The decline in gait velocity that is associated with old age is usually a sign of deterioration in one or more of these systems (Judge et al, 1993). In cross sectional studies, normal walking speeds have been found to decrease 4-8% from 20 to 60 years of age and to decrease further in older age groups (Bassey et al, 1977, 1982; Himann et al, 1988). Indeed, declines of 12-16% per decade for usual gait and about 20% for maximal gait velocity were reported for subjects 70 years of age and older (Himann et al, 1988).

A normative value of 1.2-1.4 meters (m)/sec has been documented as the mean gait velocity required to cross signalized, urban crosswalks (Aniansson et al, 1980, Hoxie & Rubenstein, 1994; Robinett & Vondran, 1988). Young
elderly people (65-75 year-old) have been reported to walk at an average speed of between 0.82-1.3 m/sec, whereas even slower gait velocities (0.60 m/sec) are characteristic of the very old (85 year-old) (Aniansson et al, 1980; Bendall et al, 1989; Ferrandez et al, 1990; Murray et al, 1969). However, these average walking speeds were determined by studying healthy subjects free of mobility impairments. Studies of frail elderly demonstrated further declines in walking speed (Bassey et al, 1992; Fiatarone et al, 1990; Leiper and Craik, 1991; Lipsitz et al, 1991; Wolfson et al, 1990). A recent study of a group of 85-90 years old frail men and women was found to have an average walking speed of 0.61 m/sec and 0.38 m/sec respectively (Bassey et al, 1992). In addition, those subjects who used a walking aid, such as a walking frame demonstrated further declines in gait velocity (0.20 m/sec). It appears therefore that the chosen walking speeds of some elderly people may decrease to functionally inadequate levels (Bendall et al, 1989). Slow gait is also an independent risk factor for hip fractures and falls (Bassey et al, 1992; Cummings et al, 1989; Imms & Edholm, 1981). Falls are known to lead to further restriction of activity, loss of confidence, mobility and independence (Nevitt et al, 1989; Vandervoort et al, 1990). Consequently, adequate
physical fitness and a functional gait are important factors for maintaining independance in old age (Judge et al, 1993).

The ability to rise unassisted from a chair is another prerequisite to many activities of daily living. Changes in sit-to-stand kinematics and kinetics may be anticipated in older persons with age-related restrictions in motion or position (Ikeda et al, 1991). In a recent study by Bassey et al (1992), a median time of 1.75 sec was reported as the time taken to rise from a chair by a group of institutionalized elderly subjects. However, only 11 subjects were able to rise freely, 14 required the use of the arms of the chair and one was unable to rise independently. This variability resulted in an interquartile range of 1.21-3.60 sec. Furthermore, those who required the use of the arms of the chair had significantly slower performance than those who were able to rise freely. Fiatarone et al (1990) studied a similar group of institutionalized, frail elderly (mean age: 90 years) and reported an average time of 2.2 sec. A longer period (mean time: 4.53 sec) was documented in a study of frail elderly residing in twelve different nursing homes (Thapa et al, 1994).
The ability to rise from a chair has been investigated as a possible predictor of falls (Campbell et al, 1989; Nevitt et al, 1989; Tinetti, 1986; Tinneti et al, 1988; Topper et al, 1993). Two prospective studies found that poor performance in rising from a chair was a strong, independent predictor of fall risk in community-dwelling elderly (Campbell et al, 1989; Nevitt et al, 1989). Indeed, a critical time of over 2 sec was documented as a significant risk factor of falls in ambulatory, frail elderly subjects (Nevitt et al, 1989). Furthermore, Topper et al (1993) reported that subjects who were unable to rise, unsteady upon standing or unsafe when sitting down were more likely to fall during a transfer compared to subjects who didn't demonstrate difficulties during the sit to stand manoeuvre. The ability to rise from a chair measured by the sit to stand time is therefore a significant indicator of mobility function and an important predictor of falls.

The TUG test is another reliable performance test of physical mobility. It represents the time taken to get up from a chair, walk 3 meters, turn and sit down. Podsiadlo and Richardson (1991) documented large variability (10-240 sec) in a group of male and female community dwelling elderly (mean age: 79.5 years). Patients who performed the test in less than 20 seconds
tended to be independently mobile. All were able to complete basic mobility skills, such as chair and toilet transfers on their own. On the other hand, the patients who scored more than 30 seconds needed the assistance of others to successfully accomplish basic mobility tasks. Difficulties in managing stairs and an inability to engage in outdoor activities unsupervised were demonstrated. The TUG score was found to be $21.7 \pm 13.9$ sec in a group of female nursing home residents (mean age: 82 years) (Connelly and Vandervoort, 1995). An even slower performance ($35.4 \pm 11.1$ sec; range: 20.1-67.4) was demonstrated in a group of frail, institutionalized male patients of the same age (Newnham et al, 1995).

The ability to manage stairs is another mobility task that is necessary for adequate functioning in everyday activities. A significant correlation was found between the ability to manage steps and difficulty in using public transportation in 79 year-old women; 61% of the women who were unable to climb up 40cm step height reported difficulty using public transportation (Lundgren-Linquist et al, 1983). Furthermore, a relatively high number of elderly demonstrate difficulties in the management of stair climbing. According to a study of normal 70 year-old elderly subjects, 67% of the men
and 72% of the women experienced difficulties in negotiating stairs, although only 2% were unable to manage (Avlund & Schultz-Larsen, 1991).

The ability to manage stairs, rise from a chair and ambulate at an acceptable gait velocity require adequate lower limb strength (Aniansson et al, 1980; Csuka and McCarthy, 1985; Danneskiold-Samsoe et al, 1984; Rantanen et al, 1996). Mobility problems may therefore be the first symptom of declining muscle strength in the elderly population. Indeed, significant correlations of lower extremity strength with these mobility functions have been reported (Aniansson et al, 1980; Bassey et al, 1992; Brown et al, 1995; Danneskiold-Samsoe et al, 1984; Fiatarone et al, 1990; Judge et al, 1993). Aniansson et al (1980) found a significant relationship ($r=0.40-0.45, p<0.05$) between gait velocity and peak values of isokinetic quadriceps muscle strength at 30, 60 and 120 deg/sec in healthy women. Fiatarone et al (1990) found a more powerful relationship ($r=0.74$) in nursing home residents over 90 years of age. Judge et al (1993) documented a relationship between lower extremity muscle strength and gait parameters at usual and fast pace among 31 subjects 82 years of age ($r=0.5-0.6, p<0.01$). A more recent report by Brown et al (1995) reported a significant association ($r=0.632, p<0.05$) between gait speed and a
summary score of the hip extensors, knee extensors and plantar flexors muscle strength in a group of 75-88 year old elderly.

A strong positive correlation was also found between stair climbing ability and lower extremity muscular strength in the elderly (Aniansson et al, 1980; Bassey et al, 1992; Danneskiold-Samsoe et al, 1984). Maximum step height and dynamic, as well as isometric muscle strength were found to be correlated (r=0.59-0.79, p<0.01-0.001) in a group of 70 year-old female subjects (Aniansson et al, 1980). Similar results were reported in a study of 80 year-old elderly men in which quadriceps strength at 60 deg/sec was found to be positively correlated (r=0.62, p<0.05) with the performance of the step test (Danneskiold-Samsoe et al, 1984). A more recent study by Bassey et al (1992) reported a strong correlation (r=0.81, p<0.001) between leg extensor power and stair-climbing speed in a group of 86-88 years old institutionalized men and women.

The sit to stand maneuver was also found to be associated with lower extremity strength. The average time taken to rise from a chair was found to be strongly correlated (r=-0.63, p<0.05) with quadriceps strength in nursing
home residents over the age of 90 (Fiatarone et al, 1990). Bassey et al (1992) reported a strong positive relationship (r=0.65, p<0.01) between chair rising speed and leg extensor power. A significant negative association (r=−0.64, p<0.05) was documented between the ability to rise from a 14 inch chair and leg extensor power (Brown et al, 1995). Resistance training programs aimed at improving lower extremity strength may therefore play an important role in the maintenance or even increase of the elderly's mobility level which may, in turn, act to improve their functional independence and quality of life.

1.3 Training Effects

Many factors including a sedentary lifestyle, chronic illness, nutritional deficiencies and aging itself are known to contribute to muscle weakness and loss of skeletal muscle mass in elderly persons (Bortz, 1982; Evans and Campbell, 1993; Fiatarone & Evans, 1993; Huber et al, 1993; Jeejeebhoy, 1986). Currently, only skeletal muscle disuse (Jones et al, 1989; Klitgaard et al, 1990) and undernutrition (Drinka and Goodwin, 1991; Efthimiou et al, 1988) are potentially preventable or reversible with targeted interventions. Partly owing to a great increase in the number of elderly in the population,
increasing attention is being paid to the role of exercise in the well being, longevity and independance of men and women aged over 65 (Aniansson et al, 1984a; Larson, 1991). Table 3 presents a summary of recent strength training studies with the elderly.

Significant strength gains ranging from 3 to 227% have been reported. This wide range of strength gains probably reflects differences between studies in duration and intensity of training, measurement techniques, as well as subjects’ baseline fitness level (Nichols et al, 1993).

Low-to-moderate resistance training has produced little or no increase in the strength of older individuals (Aniansson & Gustafsson, 1981; Aniansson et al, 1984a; Fisher et al, 1991; Larsson, 1982), although a recent study by Connelly & Vandervoort (1995) demonstrated substantial gains (47-76%) in knee extensor strength subsequent to a moderate strength training program in women. The general observation of minimal strength gains with low intensity strength training is not surprising in view of the fact that overloading the muscle is believed to be an important stimulus underlying strength gains with training (Fleck & Kramer, 1987). High intensity strength training has been
extensively studied in young to middle-age adults (Colliander & Tesch, 1992; Cote et al, 1988; Hakkinen et al., 1985; Houston et al, 1983; Ishida et al, 1990; Staron et al, 1991). There has been a reluctance to apply the overload principle to the training of older individuals because of the greater risk that may be involved with this type of program, given the age group and the presence of co-morbidity (Jette et al, 1990; Shephard, 1990). Recent reports, however, have clearly demonstrated the superiority of high intensity, dynamic resistance training for the acquisition of maximal strength even in patients of advanced age and those with chronic illness. The results demonstrated significant gains in quadriceps strength (18-174%) without any deleterious side effects to the participants (Brown et al, 1990; Charette et al, 1991; Dupler & Cortes, 1993; Fiatarone et al, 1990; Frontera et al, 1988; Lexell et al, 1995; Lord et al, 1996; McCartney et al, 1995; Nelson et al, 1994; Newnham et al, 1995; Nichols et al, 1993; Pyka et al, 1994; Rice et al, 1993; Roman et al, 1993; Sipila et al, 1996).
### TABLE 3

The Effects of Strength Training Trials on Knee Extension Strength in the Elderly

<table>
<thead>
<tr>
<th>Trial</th>
<th>Sex</th>
<th>Age (y)</th>
<th>Muscle group</th>
<th>% strength gain</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1RM</td>
</tr>
<tr>
<td>Agre et al (1988)</td>
<td>F</td>
<td>71</td>
<td>elbow ext.</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>knee flex.</td>
<td>-</td>
</tr>
<tr>
<td>Aniansson &amp; Gustafsson (1981)</td>
<td>M</td>
<td>71</td>
<td>knee ext.</td>
<td>-</td>
</tr>
<tr>
<td>Aniansson et al (1984a)</td>
<td>F</td>
<td>63-84</td>
<td>knee ext.</td>
<td>-</td>
</tr>
<tr>
<td>Charette et al (1991)</td>
<td>F</td>
<td>69</td>
<td>knee ext.</td>
<td>93</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>knee flex.</td>
<td>115</td>
</tr>
<tr>
<td>Connelly &amp; Vandervoort (1995)</td>
<td>F</td>
<td>82</td>
<td>knee ext.</td>
<td>47-76</td>
</tr>
<tr>
<td>Dupler &amp; Cortes (1993)</td>
<td>M &amp; F</td>
<td>66</td>
<td>knee ext.</td>
<td>60-80</td>
</tr>
<tr>
<td>Fiatarone et al (1990)</td>
<td>M &amp; F</td>
<td>90</td>
<td>knee ext.</td>
<td>174</td>
</tr>
<tr>
<td>Fiatarone et al (1994)</td>
<td>M &amp; F</td>
<td>87</td>
<td>knee ext.</td>
<td>113</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>knee flex.</td>
<td>227</td>
</tr>
<tr>
<td>Judge et al (1994)</td>
<td>M &amp; F</td>
<td>80</td>
<td>knee ext.</td>
<td>62</td>
</tr>
<tr>
<td>Study</td>
<td>Gender</td>
<td>Age Range</td>
<td>Muscle Action</td>
<td>Force (N)</td>
</tr>
<tr>
<td>------------------------------</td>
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</tr>
<tr>
<td>Larsson (1982)</td>
<td>M</td>
<td>22-65</td>
<td>knee ext.</td>
<td>3-8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>elbow flex.</td>
<td>163</td>
</tr>
<tr>
<td>Lord &amp; Castell (1994)</td>
<td>M &amp; F</td>
<td>62</td>
<td>knee ext.</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>Lord et al (1996)</td>
<td>F</td>
<td>71.1</td>
<td>knee ext.</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>knee flex.</td>
<td>16</td>
</tr>
<tr>
<td>Mikesky et al (1994)</td>
<td>M &amp; F</td>
<td>71</td>
<td>knee ext.</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>knee flex.</td>
<td>12</td>
</tr>
<tr>
<td>Moritani &amp; DeVries (1980)</td>
<td>M</td>
<td>70</td>
<td>elbow flex.</td>
<td>-</td>
</tr>
<tr>
<td>Nelson et al (1994)</td>
<td>F</td>
<td>61</td>
<td>knee ext.</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>sh. press</td>
<td>71</td>
</tr>
<tr>
<td>Pyka et al (1994)</td>
<td>M &amp; F</td>
<td>68</td>
<td>knee ext.</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>hip flex.</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>hip ext.</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>hip abd.</td>
<td>44</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>hip add.</td>
<td>27</td>
</tr>
<tr>
<td>Roman et al (1993)</td>
<td>M</td>
<td>68</td>
<td>elbow flex.</td>
<td>-</td>
</tr>
<tr>
<td>Sipila et al (1996)</td>
<td>F</td>
<td>76-78</td>
<td>knee ext.</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>knee flex.</td>
<td>-</td>
</tr>
</tbody>
</table>

IRM=One repetition maximum  
abd. = abduction; add. = adduction  
ext. = extension; flex. = flexion  
M = Male; F = Female  
MVC = Maximum voluntary contraction  
sh. = shoulder
There are two primary mechanisms that may underlie training-induced increases in muscle strength:

1) Morphological changes in the contractile tissue itself i.e. muscle hypertrophy and/or

2) Motor learning

It has been a widely held view that strength gains in older individuals are due to improved motor learning rather than intrinsic morphological changes (Fiatarone et al, 1994; Grimby, 1986; Grimby et al, 1992; Moritani and de Vries, 1980). However, the observed lack of muscle hypertrophy may have been due to a combination of inappropriate training threshold and measurement technique. Indeed, training intensity may have been too low in most of the earlier studies in elderly individuals (see above) to promote substantial increases in muscle size and strength. Furthermore, the potential of muscle hypertrophy may have been underestimated when measured using an anthropometric approach (Moritani and de Vries, 1980). More recent studies employing high-resistance training and more sensitive techniques of determining muscle hypertrophy (biopsy, computer tomography) have reported that muscle hypertrophy accounted for a portion of the strength gains observed in the elderly (Brown et al, 1990; Charette et al, 1991; Cress et al,
Increases in muscle cross-sectional area (CSA) averaging between 5.5-23%, with either a mixed type of hypertrophy (equal in both fiber types) or a preferential hypertrophy of type II fibers has been found. However, because the observed changes in muscle strength were consistently larger than those of muscle size, motor learning must account for part of the functional improvement (Brown et al, 1990; Fiatarone et al, 1990, 1994; Frontera et al, 1988).

Further evidence for the importance of motor learning in underlying strength gains in the elderly comes from studies that have demonstrated specificity in the strength training response and cross-training effects. A common finding in the majority of studies on training is that the greatest changes accompanying strength training can be seen in the training exercise itself rather than any objective assessment of muscle strength or size (Brown et al, 1990; Coyle et al, 1982; Dons et al, 1979; Duchateau & Hainaut, 1984; Frontera et al, 1988; Jones et al, 1989; Sale & MacDougall, 1981). Strength gains are known to be the greatest at the speed, range of motion (ROM) and type of contraction.
(concentric, isokinetic, eccentric) used in training (Fleck et al, 1981; Moffroid & Whipple, 1970). Indeed, significant strength gains ranging between 42-107% of the 1RM have been reported (Brown et al, 1990; Dons et al, 1979; Frontera et al, 1988), with either no or small gains in static or dynamic strength of elderly men. Such lack of cross-over in performance suggests that the large increase in 1RM may be attributable to the acquisition of a specific skill or improvement in coordination of the different muscle groups, which is of little value in a different task (Jones et al, 1989). In contrast, Judge et al (1994) reported a significant increase in overall lower extremity strength using outcome measures that were different from the movements performed in the training program. Still, to ensure the best possible return on the training investment one should stimulate as closely as possible the daily tasks encountered by this target population (Brown et al, 1990). This will, in turn, act to maintain or improve their level of functional independence.

Lastly, a cross-over training effect whereby training one limb has resulted in strength gains in the contralateral untrained limb offers additional evidence for the role of motor learning. Cross-over strength gains ranging from 10 to 30% have been reported in the untrained limb (Komi et al, 1978; Moritani and
DeVries, 1979). This suggests that a central mechanism exists which is able to affect both the trained and untrained limbs (Jones et al, 1989).

The training studies indicate that, given an adequate training stimulus, older subjects show similar or greater strength gains compared with young individuals after weight training (Fiatarone et al, 1990; Frontera et al, 1988, 1990). As in young people, initial gains are thought to be due to motor learning (Moritani & DeVries, 1979), while later gains are associated with muscle hypertrophy (Luthi et al, 1986; Nichols et al, 1993). However, further studies are needed to investigate the specific time course of these adaptations in the elderly.

Since muscle weakness reduces functional mobility and contributes to falls in the aged (Agre et al, 1988; Nevitt et al, 1989; Province et al, 1995; Tinetti et al, 1995), appropriate interventions may help to prevent or offset the loss of functional mobility in later life (Nichols, 1993; Province et al, 1995). Indeed, recent reports have demonstrated 6-18% gains in usual gait velocity (Fiatarone et al, 1994; Harada et al, 1995; Hunter et al, 1995; Judge et al, 1993; Lord et al, 1996; Newnham et al, 1995; Sauvage et al, 1992), 48%
increase in tandem gait speed (Fiatarone et al, 1990) and a 28% increase in stair climbing power subsequent to a high-intensity strength training program (Fiatarone et al, 1994). The TUG score, which represents the time taken to get up from a chair, walk 3 meters, turn and sit down, also showed a significant improvement (23-39%) in two groups of 66-97 year-old elderly subjects (Connelly & Vandervoort, 1995; Newnham et al, 1995). Newnham et al (1995) reported an improvement from an average of 35 sec pre-training to an average of 21 sec post-training; a reduction of this magnitude has been shown to be predictive of a higher level of functioning (Podsialdo and Richardson, 1991).

Changes in mobility functions with strength training were also found to be related to the changes in muscle strength. Significant correlations were found between the changes in the TUG scores and the changes in dynamic quadriceps strength ($r= -0.62$, $p=0.0001$; Newnham et al, 1995). In addition, significant correlations were found between the changes in mean gait velocity and the changes in dynamic quadriceps strength of the right and left leg ($r=0.58$, $p=0.01$; Newnham et al, 1995).
The aging musculoskeletal system retains its responsiveness to progressive resistance training, and most important, the correction of disuse is accompanied by significant improvement in the levels of functional mobility (Connelly & Vandervoort, 1995; Fiatarone et al, 1990, 1994; Judge et al, 1993; Newnham et al, 1995) and overall activity (Agre et al, 1988; Fiatarone et al, 1990; Fisher et al, 1991; Nichols et al, 1993).
CHAPTER 2

DEVELOPMENT OF THE STUDY

2.1 Objectives

There were two objectives for this study:

1) To determine the timing and extent of gains in strength, mobility, balance and functional status that follow a high-intensity strength-oriented rehabilitation program offered to institutionalized elderly subjects.

2) To determine whether these changes were influenced by initial mobility.

2.2 Statement of Hypothesis

The hypothesis was that a high-intensity resistance training program will have a greater impact on strength, mobility and balance in elderly people with mobility impairment (LOW) in comparison to those with good mobility (HIGH).
2.3 Research Design

This study consists of a two group parallel cohort design (or a two group comparative study). A HIGH and a LOW mobility group took part in a 12 week high-intensity resistance training program. The differential effect of this regimen on strength, mobility, balance, functional status and quality of life was compared in the two groups.

2.4 Clinical Setting

This study took place in the Physiotherapy department of Ste Anne's Hospital which is located in the West Island of Montreal. This is a 700 bed long-term care institution administered by the Government of Canada's Department of Veteran's Affairs. The population includes mostly men (~95% male) who suffer from various chronic disabilities. Nursing care, as well as medical and paramedical services are routinely provided in the facility.
2.5 Study Population

Subjects were drawn as a sample of convenience from the in-patient population of the hospital. Initial screening included the patients who met the following criteria:

1) No known history of an unstable cardiovascular condition

2) Absence of any co-morbid conditions that may interfere with the patient's ability to participate in the exercise program. These may include rapidly progressing or terminal disease (for example, terminal cancer), lower extremity amputation, fracture of the lower extremity within the six months before the study, acute or chronic musculo-skeletal conditions

3) No participation in any lower extremity strength training program within the past three months

4) Ability to stand and ambulate over a minimum distance of five meters

5) Having sufficient cognitive skills to follow multistep commands and perform the exercise routine without constant supervision or direction (score greater than 20 on the Folstein mini-mental state test (Folstein et al., 1975; Tinetti et al, 1993).

The second step of the screening process involved acquiring medical clearance from the patient's attending physician and a signed informed consent from the patient himself. Those eligible and willing to participate were then more fully evaluated and classified as a person with HIGH or LOW
mobility based on the TUG score (< 20 sec or ≥ 20 sec respectively). Individuals who perform the TUG test in less than 20 seconds tend to be independently mobile. They are able to complete chair and toilet transfers without assistance and have reasonable balance and a functional gait speed. On the other hand, those who take longer to complete the test often require the assistance of others to perform basic mobility tasks (Podsiadlo and Richardson, 1991). All necessary screening procedures were conducted by a member of the rehabilitation team (physical or occupational therapist) at the hospital. The last step involved the process of simple random sampling in which an appropriate and equal number of subjects was selected from each stratum (i.e. LOW and HIGH mobility groups).

2.6 Determination of Sample Size

Sample size calculation was based on the estimated mean difference from initial to final and the within group standard deviation in the LOW and HIGH groups. The main outcome measure (TUG score) was used in the calculation. With an alpha level of 0.05 and a beta level of 0.10, corresponding to a power
(1-beta) of 0.90, the following formula was used to estimate the total number of subjects required for this study:

\[ N = 4 \left( Z_{\alpha} + Z_{\beta} \times \frac{\text{standard deviation}}{\text{difference}} \right)^2 \]

where
- standard deviation = value of the source population standard deviation
- difference = the expected clinically important difference

In the LOW group, the mean difference in change from initial to final and the within group standard deviation were estimated to be 7 and 7 seconds respectively. In the HIGH group, these values decreased to 3 and 3 seconds respectively. This data were derived from a pilot study done on a select group of mobility impaired, elderly, institutionalized men and previous clinical experience (Newnham et al, 1995). These values were also in accordance with a recent study of relatively high mobility individuals that documented a 4 seconds change in the TUG score (Connelly and Vandervoort, 1995).

Using these parameters, an estimated sample of 13 subjects per group would provide 90% power, with a risk of a type I error of 0.05. However, a relatively high attrition rate (25%) was an additional factor to consider in the calculation of the sample size due to the advanced age, chronic disability and
comorbidity present in this type of patient population. In a previous trial in Ste Anne's Hospital in which a group of mobility impaired elderly subjects took part in a similar type of exercise program, the drop out rate over a 3 months period has been calculated to be 20% (Newnham et al, 1995). Three previous clinical trials (Fisher et al, 1991; Morey et al, 1989; Sipila & Suominen, 1995) reported a drop out rate of between 22% and 26%. The impact of this factor necessitated the addition of three subjects to each group resulting in a total number of 32 subjects.
CHAPTER 3

METHODS AND PROCEDURES

3.1 Study Variables

The study's variables included dynamic strength, mobility, balance, functional level and psychological status. These were measured by a physiotherapist external to this study. The TUG, 1RM and the Berg were included as the primary measures. Habitual gait velocity, the COVS and the GDS were considered as secondary.

3.1.1 Muscle strength

Dynamic strength was measured with the 1 RM. This represents the amount of weight that can be successfully lifted through one full ROM with proper technique and acceptable form (McDonaugh and Davies, 1984). The strength of both legs was evaluated before, every two weeks during and after the intervention program by a certified physical therapist. The 1RM was used to determine the training load (80 % of the 1RM). It was tested every 2
weeks in order to readjust the training weights. These measurements were obtained using a quads table (Physio E.R.P. Limited, ERP7645).

The 1RM was established using the same protocol developed by Newnham et al (1994). The subjects were placed in a sitting position, with the back well supported by a wedge-shaped foam cushion and the hip positioned at 90 degrees of flexion. High interrater and intrarater reliability (Intraclass Correlation Coefficient (ICC)=0.99) were established with this type of patient population (Newnham et al, 1994). Initially, the subjects underwent one to two lifts without any weight to familiarize them to the task and to warm up. Minimal resistance was then added to determine acceptable performance of the lift, as well as to establish the point of maximum knee extension that the subject is able to perform. The initial load was selected to achieve the maximum weight within four to five trials. A minimum load of 2.2 kilograms (kg) was used. It was then gradually increased based on the subject's perceived difficulty and the evaluator's observation of the ability to maintain acceptable form, until the subject was not able to complete a lift. Approximately 60 seconds rests were given between lifts. Furthermore, each lift was performed slowly and held at the end of the range of movement for
three seconds. Verbal encouragement was given to each subject during the lifts.

3.1.2 Mobility Function

The TUG test (Podsiadlo and Richardson, 1991) which is a modification of an earlier version called the "Get-Up and Go" test (Mathias et al, 1986) was used. The subject's back was placed in contact with a straight-back chair and the arms were on the arm rests. Upon the command "go", the subject got up, walked to a line on the floor 3 meters away, turned, returned and sat down. The subject was timed using a stop-watch on two consecutive trials and the average of the two was taken as his respective TUG score. Appropriate foot wear was worn and the subject used his customary walking aid. Furthermore, no physical assistance was given by the examiner during the testing period. The test-retest and interrater reliability of the TUG have been established in a group of institutionalized individuals (ICC=0.99 and 0.98 respectively) (Newnham et al, 1994). This test's validity has also been demonstrated by significant correlations between the timed test score and the log-transformed scores of the Barthel Index of Activities of Daily Living (r=--
0.78), gait speed ($r=-0.61$) and the Berg ($r=-0.81$) in a group of community dwelling elderly (Podsialdo and Richardson, 1991).

Habitual walking speed was tested as a secondary measure of mobility level. It was performed over a distance of 25 m, with the initial 5 m used as a warm-up and the last 5 m as a deceleration period. Only the middle 15 m was timed. A chrono mode of Timex Quartz Ironman watch was used. All subjects were instructed to use their usual walking aid. This method has been used by several authors (Aniansson et al, 1980; Buchner et al, 1996; Danneskiold-Samsoe et al, 1984; Lundgren-Linquist et al, 1983; Newnham et al, 1995) and an inter-rater and test-retest reliability of 0.90 and 0.88 respectively have been reported with a group of institutionalized elderly subjects (Newnham et al, 1994). This performance-oriented outcome measure therefore provided a reliable measure of the subject's comfortable walking speed.

Both mobility tests were administered prior and after the training program and once a month during the intervention by a certified physiotherapist.
3.1.3 Balance

The Berg which is a performance based measure of balancing ability was used. This measure consists of 14 ADL related-tasks scored on a 5-point ordinal scale. The items in the scale address the subject's ability to maintain or change positions of increasing difficulty by diminishing the allotted base of support. The ICC for test-retest, intra and interrater reliability were found to be 0.99, 0.98 and 0.99 respectively in a group of elderly people, demonstrating excellent agreement (Berg et al, 1992; Newnham et al, 1994). Additionally, the internal consistency of the Berg was found to be high (Cronbach's L=0.96), indicating that the scale is measuring one underlying concept. Its validity was also demonstrated by significant correlations between the Barthel Mobility sub-scale (r=0.67), as well as the TUG score (r=-0.76) (Berg et al, 1992). The Berg was administered prior and after the training program and once a month during the intervention period.

3.1.4 Functional status

The COVS was used to measure the subjects' functional level as a secondary outcome measure. The COVS consists of 13 items measuring different
aspects of function, such as ambulation, bed and chair transfers, bed mobility and arm function. Each item is scored on an ordinal scale ranging from 0 to 7 demonstrating ascending levels of functioning from non-functional to independence (Seaby, 1987).

Internal consistency of the scale was found to be high (alpha=0.92). Intra and inter-rater reliability were also tested on a group of 100 rehabilitation patients with neurological and musculo-skeletal conditions. Intra and inter-rater reliability of the individual items were found to be relatively good (weighted kappa= 0.66-0.98). Inter-rater reliability of the composite scale designated excellent agreement (ICC=0.97) (Seaby and Torrance, 1989).

The test's concurrent (criterion) validity has also been demonstrated by significant correlations (spearman’s rho=0.52-0.94, p<0.001) between individual items of the COVS and mobility items of the Health Status Rating Form (HSRF) and the Kenny Self Care Evaluation Index (Kenny). In addition, strong correlations (r=0.87-0.95, p<0.01) between summary scales of the COVS, HSRF and Kenny evaluations have been documented (Seaby, 1987). Evidence of construct validity has been illustrated by a low but
significant correlation \((r=-0.21, p=0.04)\) between the COVS score and the age of non-spinal cord patients, whereby older individuals were shown to have lower COVS scores. The expectation that mobility summary scores would be different for quadriplegics when compared with other patients was also tested as further evidence for construct validity. Indeed, the mean score of quadriplegics was the lowest (27.7) followed by stroke patients (49.8) (Seaby, 1987).

The COVS was administered prior to the start of the exercise regimen as a baseline measure and once after the program was completed.

### 3.1.5 Psychological status

The GDS was used as a measure of the subjects' depression level. This evaluation was developed by Yesavage et al in 1983 and focuses on the emotional factors of depression. The GDS consists of 30 items with binary response categories (yes-no). It was found to be easily comprehensible to older patients and takes about 5 minutes to complete (Koeing et al, 1988).
The GDS demonstrates high internal consistency and test-retest reliability (Cronbach's alpha=0.94 and \( r=0.85 \) respectively) (Yesavage et al, 1983). It has been validated for community dwelling, well elderly and hospitalized elderly and was found to be useful with patients whose Folstein's mini mental state score is greater than 15 (Hamilton, 1967; Koeing et al, 1988; McGivney et al, 1994; Steuer et al, 1984). A relatively strong criterion validity (kappa=0.62) was determined by comparing the GDS scores with the results of structured psychiatric interviews following the Diagnostic and Statistical Manual of Mental Disorders (DSM-III) diagnosis criteria in a group of 128 hospitalized elderly (Koeing et al, 1988). The highest combined sensitivity and specificity for this test, namely 92% and 89% respectively, occurred at a cut-off score of 11 as determined by receiver operating characteristics curves. In addition, the negative predictive value at this score was 99% implying that scores less than 11 virtually exclude the diagnosis of major depression (Koeing et al, 1988). The GDS was administered prior to the start of the exercise program and at the end of the training regimen.
3.1.6 Confounding Variables

Several variables have been identified as possible confounding factors susceptible of influencing the outcome; these include: length of time in institution, age, gender, medication use, presence of co-morbidity, nutritional status, present and past level of physical activity and depression level. The first six factors were obtained from the patient's hospital records. The presence or absence of the following conditions was determined: stroke, Parkinson's disease, alcoholism, AIDS, visual deficits, chronic obstructive pulmonary disease, congestive heart failure, arthritis, diabetes, hearing impairment, hypertension, kidney disease, liver disease, lymphoma, leukemia, arteriosclerotic heart disease, metastatic cancer (solid tumors), old myocardial infarct, peripheral vascular disease, smoking, etc.

A measure of body composition, namely the body mass index (BMI), was used as an indicator of the subject's nutritional status. BMI was calculated as the weight in kilograms divided by the square of the height in meters (Deurenberg et al, 1990; Fiatarone et al, 1994).
Present and past level of physical activity was evaluated with a questionnaire based on the approach of Washburn et al. (1987) in order to obtain a global picture of the patients' physical activity level. The life span was divided into five time periods (14-30, 31-50, 51-retirement, retirement-institutionalization, and present) as suggested by Kriska et al. (1988) and the subject was asked to answer the following question: Compared with others your age and sex would you consider yourself to be: (IV) Much more active, (III) Somewhat more active, (II) About the same, or (I) Somewhat less active. The total score was calculated by simply adding the numbers together. More comprehensive physical activity questionnaires specifically for the elderly have only recently been developed (Casperson et al., 1994; Dipietro et al., 1993; Voorrips et al., 1991; Washburn et al., 1993) but they are not applicable to the institutionalized elderly population (Refer to Appendix no. 1 for a copy of the evaluation form). Depression level was evaluated with the GDS.

3.2 Treatment Procedures

The two groups participated in two separate supervised individual programs of exercises, taking place three days per week, for 12 weeks. One day rest between the exercise sessions was implemented to allow for an adequate
recovery period (Fleck and Kraemer, 1987). The length of the program has been chosen to increase the potential for morphological and neural adaptations, as training programs shorter than 8 weeks have been shown to lead to minimal muscle hypertrophy (Moritani and deVries, 1980).

The training sessions were conducted under the supervision and guidance of a licensed physiotherapist in order to ensure proper technique and decrease the risk of injury. In addition, no more than three-four subjects trained at any time to provide adequate supervision. Each session lasted approximately 30-45 minutes. A warm up period of 10 minutes on a stationary bike with no resistance or on a treadmill was given.

The 12 week program was designed to utilize a high resistance, low repetition approach to strength training. The target load was therefore maintained at or near 80% of the 1RM and three sets of 8-10 repetitions were performed with about two minutes rest between the sets. However, during the first few weeks the target load was set at a lower intensity (50% of the 1RM) to ensure the subject's safety and allow for a gradual progression of the exercise routine. The weight resistance was gradually progressed according to the subject's
response. This took place when the subject was able to easily complete all three sets to the maximum of 10 repetitions. The exercises were designed to stimulate the strength-requiring tasks likely to be encountered in daily life by the institutionalized elderly population. The main focus of the program was therefore placed on the lower extremity. Muscles around the hip, knee and ankle were exercised. Functionally-oriented exercises were also included; rising from various chair heights and stair climbing using a graded step height were integrated into the exercise routine. These functional exercises were progressed by either adding weights around the subject's waist or at the shoulder.

Compliance was also measured by keeping a record of the times that subjects did or did not come for treatment. The data analysis, however, was conducted on the total number of subjects, irrespective of their compliance (intent-to-treat). Non compliant subjects were defined as those who missed more than 20 % of the treatment sessions. Information on the reasons for the absence was collected in both groups (HIGH and LOW) and then compared.
3.3 Data Analysis

The objective of this study was to ascertain and compare the extent and timing of gains in strength, mobility, balance, functional level and psychological status that follow a strengthening program offered to two groups of elderly subjects (i.e. a LOW and a HIGH mobility group). First, unpaired student's t-tests were completed to determine whether the following variables differed between the two groups at baseline: age, nutritional status, length of time in institution, medication use, previous and current activity level, prevalence of associated co-morbidity and depression level. Secondly, the means and standard deviations of each outcome variable for the group as a whole were examined at each point in time [0(T0), 1(T1), 2(T2) and 3(T3) months] and change scores were calculated for every time interval (T1-T0, T2-T1, T3-T2 and T3-T0). For example, a change score in muscle strength from 1 to 2 months was calculated according to the following formula:

\[
\text{IRM group mean at T2 - IRM group mean at T1}
\]

Training effects in the various time intervals were also examined by calculating the percentage improvement during a particular time interval as a part of the total gain (T3-T0). For example, the percentage improvement in
muscle strength during the first time interval (T1-T0) was calculated using the following formula:

\[
\frac{100 \times (1RM \text{ group mean at T1} - 1RM \text{ group mean at T0})}{(1RM \text{ group mean at T3} - 1RM \text{ group mean at T0})}
\]

This was done to illustrate differences in gains over time in the two exercise groups.

Thirdly, overall gains following the 12 weeks of training in the LOW and HIGH mobility groups were examined as percentages of proportional change. The following formula was utilized in the calculation:

\[
\frac{100 \times (\text{final test score (T3)} - \text{initial test score (T0)})}{\text{initial test score(T0)}}
\]

Gains in strength, mobility, balance, functional and psychological status in the two training groups were then compared. In order to verify the hypothesis that subjects in the LOW mobility group have a greater potential for improvement in comparison to those in the HIGH mobility group simple correlations were completed between the percentage of proportional change and the patient's baseline status.
The effects of the training program on strength, balance and mobility were examined using a 2 x 4 repeated measures analysis of variance (ANOVA) with one between-subjects factor (group) and one within-subject factor (4 time periods). The COVS and the GDS score were examined using a 2 x 2 repeated measures ANOVA as these outcome measures were evaluated twice: prior to the start of the intervention and following the 12 weeks of training. Results from the ANOVAs were also examined to determine whether there was an interaction between the two factors (i.e. group and time). More specifically, this type of statistical test examined whether changes across time in the various outcome measures were consistent across the two groups. Newman-Keuls post hoc analyses were conducted to determine the source of any differences identified by the ANOVAs.

All tests were conducted at a significance level of $p < 0.05$.

3.4 Ethical Considerations

This proposed research study was submitted and received approval from the Ethics committee of the School of Physical and Occupational Therapy of
McGill University, as well as the Research Committee of Ste. Anne's hospital.

Every subject participating in the study signed an informed consent (Appendix 2) prior to the start of the exercise program. The objectives and the methodology procedures were explained to the subjects before they signed this consent. The subjects were also given medical clearance by the attending physician in order to take part in the exercise program. Strict confidentiality was maintained relating to the patient's identity and participation in the study.

The subjects were supervised by competent professionals (Physiotherapist and Occupational Therapist) at all times. Assistance was provided as needed, including all transfers to and from the training equipment. Progression through the exercise regimen was paced according to the individual's response to the training program.

At any time, a subject had the right to withdraw from the study without prejudice or could have been withdrawn for medical reasons. Any subject
who refused to take part in the study followed the regular ward routine during the duration of the study.

No invasive procedures took place during the course of the study.
CHAPTER 4

RESULTS

4.1 Subject Characteristics

Subjects were drawn as a sample of convenience from the in-patient population of Ste-Anne’s hospital. Fifty four individuals met the inclusion criteria (refer to page 31) and were then stratified as a person with high or low mobility based on the TUG score (<20 or ≥ 20 sec respectively). The last step involved the random selection of sixteen subjects forming each stratum forming a LOW and a HIGH mobility group. Significant differences in walking speed (p<0.001) and functional status (p<0.01) were found between the two groups at baseline further supporting the fact that these groups were, in fact, different prior to the start of the exercise program. In addition, the primary mode of locomotion in the LOW mobility group was a wheelchair and a walker (used for long and short distances respectively). By comparison, 85.6% of the subjects in the HIGH mobility group used a cane or no assistive device in their ambulation. Initial strength measurements, however, were not found to be significantly different between the two groups.
Comparison of the LOW and HIGH mobility groups on possible confounding variables concluded that the two groups were similar in age, nutritional status (height/weight$^2$), length of time in institution, number of diagnoses, number of medications taken, past and present physical activity level and mini mental status (Table 4). They differed, however, in their baseline depression level as measured by the GDS ($p=0.0029$).

In the LOW mobility group, three subjects withdrew their consent and did not wish to participate in the exercise program prior to the start of the study. In addition, three subjects were not able to participate for a medical reason (e.g. deterioration in mental/physical status). Lastly, one subject wished to visit his wife for periods of 2 weeks at a time preventing him from being able to attend the exercise program regularly. As a result, the LOW mobility group consisted of a final size of nine subjects.

Nine subjects withdrew from the HIGH mobility group. Three subjects withdrew from the program as the exercises did not meet their expectations. Two subjects were dropped out due to extremely poor compliance ($<50\%$ attendance rate) and refusal to come for evaluations. Four subjects were not
able to continue due to a medical problem (e.g. deterioration of psychiatric mental status, development of pneumonia). As a result, the HIGH mobility group consisted of a final sample size of seven subjects. In total, 16 subjects completed the post-training evaluations.

The attendance rate of the LOW and HIGH mobility groups were high (94% and 89% respectively). Subjects who missed three consecutive sessions were asked to attend the exercise program for an additional week. This occurred with three patients due to the development of an acute medical problem.
TABLE 4
Baseline Subject Characteristics

N=16

<table>
<thead>
<tr>
<th>Variables</th>
<th>LOW Mobility Group N=9</th>
<th>HIGH Mobility Group N=7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (Years)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>78.7 ± 4.8</td>
<td>79.1 ± 4.8</td>
</tr>
<tr>
<td>Nutritional status (Kg/ M2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>24.8 ± 3.5</td>
<td>25.5 ± 4.5</td>
</tr>
<tr>
<td>Length of time in institution (Months)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>22.4 ± 23.7</td>
<td>100.6 ± 121.0</td>
</tr>
<tr>
<td>Number of diagnoses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>6.7 ± 2.0</td>
<td>6.1 ± 2.7</td>
</tr>
<tr>
<td>Number of medications</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>5.4 ± 1.4</td>
<td>3.1 ± 2.5</td>
</tr>
<tr>
<td>Mini mental status</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>23.9 ± 2.1</td>
<td>26.3 ± 3.2</td>
</tr>
<tr>
<td>Depression level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>13.0 ± 5.6</td>
<td>3.9 ± 3.9 *</td>
</tr>
<tr>
<td>History of physical activity level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>10.5 ± 2.3</td>
<td>13.1 ± 2.9</td>
</tr>
</tbody>
</table>

* p < 0.05
4.2 Muscle Strength

Dynamic strength was evaluated using the 1RM recorded in kilograms. The knee extension strength of the right and left lower extremity was averaged to give one single value at each testing time [0(T0), 1(T1), 2(T2) and 3(T3) months]. A 2 x 4 repeated measures ANOVA indicated that there was a significant main effect for time (F=22.3, p<0.0001) (Table 5 and 6). Post hoc analyses using a Newman-Keuls procedure reported significant differences in both the LOW (p<0.01-0.05) and HIGH (p<0.05) mobility groups between the pre-training 1RM measurements and those taken at the 1, 2 and 3 month time periods. In addition, the 1 month mean 1RM score in the LOW mobility group was significantly different from the group average 1RM score obtained at the 2 and 3 month time periods (p<0.01). No significant interaction between the factors group and time was present (F=1.8, p=1.6).

Overall, the percentage increase in the 1RM of the LOW and HIGH mobility group following 12 weeks of training was 121.2% and 81.3% respectively. Significant correlations were found between the percentage of proportional change and the subject’s initial strength level (r=-0.94 and r=-0.88, p<0.01 in the LOW and HIGH mobility groups respectively).
Change scores in the two training groups were calculated for every time interval (T1-T0, T2-T1, T3-T2 and T3-T0) to examine the gains in muscle strength over time (Table 7). In the LOW mobility group, 36.5%, 49.2% and 14.3% of the total improvement in muscle strength (T3-T0) took place in the three time intervals respectively. By comparison, 66.7%, 16.7% and 16.7% of the overall improvement occurred in the three time intervals of the HIGH mobility group respectively. In both groups most of the total improvement occurred during the first 2 months of the training program (85.7% and 83.4% respectively).
<table>
<thead>
<tr>
<th></th>
<th>Time 0</th>
<th>Time 1</th>
<th>Time 2</th>
<th>Time 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Quads 1RM (Kg)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>6.2 ± 2.0</td>
<td>8.5 ± 1.9</td>
<td>T0-T1 *</td>
<td>T1-T2 **</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>T0-T2 **</td>
<td>T0-T3 **</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>11.6 ± 1.9</td>
<td>12.5 ± 2.2</td>
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<tr>
<td><strong>Berg Balance Scale</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>29.5 ± 11.3</td>
<td>31.8 ± 10.4</td>
<td>T0-T2 *</td>
<td>T0-T3 *</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>T1-T2 *</td>
<td>T1-T3 *</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>35.8 ± 8.3</td>
<td>38.9 ± 5.9</td>
</tr>
<tr>
<td><strong>TUG test (sec)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>38.8 ± 12.0</td>
<td>32.1 ± 12.2</td>
<td>33.9 ± 13.1</td>
<td>34.3 ± 12.2</td>
</tr>
<tr>
<td><strong>Walking speed (m/sec)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>0.40 ± 0.14</td>
<td>0.46 ± 0.15</td>
<td>0.43 ± 0.17</td>
<td>0.44 ± 0.12</td>
</tr>
<tr>
<td><strong>COVS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>69.2 ± 10.1</td>
<td>-</td>
<td>-</td>
<td>70.8 ± 7.3</td>
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<tr>
<td><strong>Depression Level (GDS)</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>13.0 ± 5.6</td>
<td>-</td>
<td>-</td>
<td>10.9 ± 5.5</td>
</tr>
</tbody>
</table>

* p < 0.05    ** p < 0.01

Times 0,1,2,3 = Pre training, 1, 2 and 3 months into the exercise program
Quads = Quadriceps
1RM = One repetition maximum
TUG = Timed Up and Go
COVS = Physiotherapy Clinical Outcome Variables
GDS = Geriatric Depression Scale
TABLE 6
Dynamic Strength, Balance, Mobility, Functional Status and Depression

Level in the HIGH Mobility Group at the four Testing Times

N=7

<table>
<thead>
<tr>
<th></th>
<th>Time 0</th>
<th>Time 1</th>
<th>Time 2</th>
<th>Time 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Quads 1RM (Kg)</strong></td>
<td>6.6 ± 1.9</td>
<td>9.4 ± 4.3</td>
<td>10.1 ± 3.9</td>
<td>10.8 ± 2.4</td>
</tr>
<tr>
<td>Mean ± SD</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>Berg Balance Scale</strong></td>
<td>48.6 ± 6.1</td>
<td>50.8 ± 3.1</td>
<td>51.1 ± 2.6</td>
<td>50.9 ± 1.9</td>
</tr>
<tr>
<td>Mean ± SD</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TUG test (sec)</strong></td>
<td>13.3 ± 2.45</td>
<td>15.1 ± 5.8</td>
<td>12.9 ± 3.1</td>
<td>13.5 ± 2.4</td>
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<tr>
<td>Mean ± SD</td>
<td></td>
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<tr>
<td><strong>Walking speed</strong></td>
<td>0.94 ± 0.18</td>
<td>0.86 ± 0.15</td>
<td>0.96 ± 0.16</td>
<td>0.87 ± 0.23</td>
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<tr>
<td>(m/sec)</td>
<td></td>
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<td></td>
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<tr>
<td>Mean ± SD</td>
<td>83.0 ± 5.9</td>
<td>-</td>
<td>-</td>
<td>85.1 ± 4.12</td>
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<tr>
<td><strong>COVS</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>3.9 ± 3.9</td>
<td>-</td>
<td>-</td>
<td>3.9 ± 3.7</td>
</tr>
<tr>
<td><strong>Depression Level</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(GDS)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean ± SD</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

* p < 0.05

Times 0, 1, 2, 3 = Pre training, 1, 2 and 3 months into the exercise program
Quads = Quadriceps
1RM = One repetition maximum
TUG = Timed Up and Go
COVS = Physiotherapy Clinical Outcome Variables
GDS = Geriatric Depression Scale
TABLE 7

Group Average Change Scores of Dynamic Strength, Balance and Mobility Level in the LOW and HIGH Mobility Groups at the four Testing Times

N=16

<table>
<thead>
<tr>
<th></th>
<th>T1-T0 (1st month)</th>
<th>T2-T1 (2nd month)</th>
<th>T3-T2 (3rd month)</th>
<th>T3-T0 (Total)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Quads 1RM</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L.M. Group</td>
<td>+2.3</td>
<td>+3.1</td>
<td>+0.9</td>
<td>+6.3</td>
</tr>
<tr>
<td>H.M. Group</td>
<td>+2.8</td>
<td>+0.7</td>
<td>+0.7</td>
<td>+4.2</td>
</tr>
<tr>
<td><strong>Berg Scale</strong></td>
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<td></td>
</tr>
<tr>
<td>L.M. Group</td>
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<td>+4.0</td>
<td>+3.1</td>
<td>+9.4</td>
</tr>
<tr>
<td>H.M. Group</td>
<td>+2.2</td>
<td>+0.3</td>
<td>-0.2</td>
<td>+2.3</td>
</tr>
<tr>
<td><strong>TUG test</strong></td>
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</tr>
<tr>
<td>L.M. Group</td>
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<td>+1.8</td>
<td>+0.4</td>
<td>-4.5</td>
</tr>
<tr>
<td>H.M. Group</td>
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<td>+0.2</td>
</tr>
<tr>
<td><strong>Gait speed</strong></td>
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<tr>
<td>L.M. Group</td>
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<td>-0.03</td>
<td>+0.01</td>
<td>+0.04</td>
</tr>
<tr>
<td>H.M. Group</td>
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<td>+0.10</td>
<td>-0.09</td>
<td>-0.07</td>
</tr>
</tbody>
</table>

Times 0,1,2,3 = Pre training, 1, 2 and 3 months into the exercise program
Quads = Quadriceps
1RM = One repetition maximum
L.M. Group = LOW mobility group
H.M. Group = HIGH mobility group
Berg Scale = Berg Balance Scale
TUG = Timed Up and Go
4.3 Balance ability

The subject's balance ability was measured using the Berg test. A 2 x 4 repeated measures ANOVA found a significant main effect for time (F=7.40, p=0.0004), as well as a significant interaction between the factors group and time (F=3.21, p=0.03). The changes in balance ability across time were, therefore, not consistent across the two groups. Post hoc comparisons using Newman-Keuls procedure showed that the pre-training and 1 month mean Berg score in the LOW mobility group were significantly lower than the group average Berg score obtained at the 2 and 3 month time periods (p < 0.05). In contrast, the change in the balance ability of the HIGH mobility group subsequent to the exercise program did not reach statistical significance (Table 5 and 6).

Overall, the percentage increase in the Berg of the LOW and HIGH mobility groups following 3 months of training was 49.3% and 6.2% respectively. Significant correlations were found between the percentage of proportional change and the initial Berg score in the LOW and HIGH mobility groups (r=-0.83 and r=-0.99, p<0.01). Change scores in the LOW mobility group were also calculated for each time interval (T1-T0, T2-T1, T3-T2 and T3-T0) to
examine the gains in the balance level over time (Table 7). It was noted that 24.5%, 42.6% and 33.0% of the overall improvement in the subject’s balance ability (T3-T0) took place in the three time intervals (T1-T0, T2-T1, T3-T2) respectively.

4.4 Mobility functions

The mobility level of both training groups was measured using the TUG and the average walking speed test. In general, partly due to the large variability in the training response, the average mobility level of the LOW and HIGH mobility groups stayed the same during the 3 months period (Table 5 and 6). However, a significant interaction between the factors group and time was found by examining the changes in the TUG test over time (F=3.58, p=0.02). Post hoc analysis using a Newman-Keuls procedure reported a statistically significant difference (p<0.05) between the pre-training and 1 month, as well as a trend toward improvement (p=0.06) between the initial and the 3 month group average TUG score in the LOW mobility group. Changes in the walking speed test over time failed to reach statistical significance (F=0.89, p=0.45). However, a trend was found between the subject’s percentage
change in walking speed following 12 weeks of training and the initial gait velocity \((r=-0.60 \text{ and } r=-0.43, p>0.05\) in the LOW and HIGH mobility groups respectively). A low correlation was also present between the initial TUG score and the percentage change in the TUG test subsequent to the exercise program in the HIGH mobility group \((r=0.38, p>0.05)\).

### 4.5 Functional Status

Functional status was measured using the COVS. The COVS scores of the subjects in the LOW and HIGH mobility groups did not change significantly following the 12 week exercise program \((F=1.93, p=0.20\) and \(F=3.95, p=0.094\) respectively) (Table 5 and 6). Furthermore, there was no interaction between the factors group and time \((F=0.03, p=0.87)\).

### 5.6 Psychological status

Depression level was measured using the GDS. No statistically significant difference was observed in the LOW or HIGH mobility groups following 12 weeks of training \((F=0.71, p=0.41)\) (Table 6 and 7). However, a 16.2%
reduction in the group average GDS score (13.0→10.9) was documented in the LOW mobility group. This decline may be clinically relevant bearing in mind that 11 is the reported cut-off score for depression.
CHAPTER 5

DISCUSSION

5.1 Effects of Training on Muscle Strength

Significant gains (121.2%) in dynamic quadriceps strength were reported in the LOW mobility group subsequent to the 12 week high-intensity resistance training program. These results compare favorably with 1RM increases of 113.0% to 174.0% documented in recent trials with similar groups of frail institutionalized and nursing home residents (Fiatarone et al, 1990, 1994). By comparison, two recent studies investigating the effects of exercise on institutionalized men and women reported relatively smaller benefits (47.0-61.0%) (Connelly and Vandervoort, 1995; Newnham et al, 1995). However, the subjects in the latter two studies (Connelly and Vandervoort, 1995; Newnham et al, 1995) were 17.7-67.7% stronger at baseline as compared to the participants of the present study.

Subjects in the HIGH mobility group also improved significantly following the training regimen. The group average quadriceps strength increased by 81.3% over the 12 week time period. Other studies of elderly men and women with
relatively high mobility levels reported 1RM gains of 32.0-112.0% following 11-13 weeks of training (Charette et al, 1991; Dupler and Cortes, 1993; Frontera et al, 1988; Hunter et al, 1995; Judge et al, 1993, 1994; Pyka et al, 1994). All these studies included small samples (mean sample size: 16) of community dwelling elderly individuals.

Great variability in the strength gains following the exercise program was apparent in the results of this study. Dynamic muscle strength gains ranged from 19.1-286.3% and 0.8-243.3% in the LOW and HIGH mobility groups respectively. It is important to examine this variability in order to understand who would most likely benefit from training programs. A very high negative correlation (r=-0.95 and r=-0.88, p<0.01 in the LOW and HIGH mobility groups respectively) was present between the percentage of increase in muscle strength and the initial strength level of the subjects. The individuals who gained the most in the LOW and HIGH mobility groups were those with the lowest reported 1RM score prior to the start of the exercise program, while those with the greatest initial force showed modest improvements. For example, one subject in the LOW mobility group, who was able to lift only 2.4 kg at baseline improved by 286.3% over the 12 week period. By
comparison, a subject who was initially lifting 8.6 kg (258% more) increased his dynamic strength by only 0.8%. This trend was also apparent in other strength studies involving elderly subjects (Fisher et al., 1991; Judge et al., 1994; Lexell et al., 1995). Lexell et al. (1995) reported a significant negative relationship \( r = -0.42, p < 0.05 \) between the baseline strength level and the percentage increase following the exercise program. In addition, relatively strong subjects (1RM > 10kg) showed little, if any, improvement following a 6 week muscle rehabilitation program with 18 nursing home residents (Fisher et al., 1991). In conclusion, it appears that targeting relatively weak subjects (1RM: 2.4-6.4kg) leads to significantly high gains in dynamic muscle strength (89.3-286.3%).

In both groups most of the total improvement occurred during the first two months of the training program (85.7% and 83.4% in the LOW and HIGH mobility groups respectively) (Table 7). Similar results were documented by Pyka et al. (1994) whereby exercisers showed significantly increased strength (65%) during the initial two months after which further changes in strength tended to plateau. However, initial gains in muscle strength during training are thought to be related to improvements in motor control, while later gains are
often associated with muscle hypertrophy (Brown et al., 1990; Charette et al., 1991; Frontera et al., 1988; Larsson, 1982). Therefore, longer periods of training may be more suited to bring about more permanent muscle changes, namely morphological changes, following exercise programs with elderly individuals. Indeed, recent trials reported significant increases in type I and II quadriceps fiber areas (20.0-27.6%, p<0.02-0.001), a 10.6% (p<0.01) gain in quadriceps CSA and a 17.4% (p<0.01) improvement in the mean maximal biceps CSA following 12-15 weeks of training with elderly subjects (Brown et al., 1990; Charette et al., 1991; Frontera et al., 1988; Larsson, 1982).

The initial group average muscle strength at baseline was similar in the LOW and HIGH mobility groups (6.2kg and 6.6kg respectively). This could be related to differences in testing procedure between the two groups at baseline. The testing of the 1RM involves instructing the subject to lift his leg to the point of maximum knee extension and hold the weight at that range for 3 sec. Weights are added gradually until the subject is unable to complete a lift. The knee angle at which the quadriceps muscle strength is being tested has a large impact on the measurement of strength.
The muscle is reported to be the strongest at a knee angle of 60 deg and the weakest at 0 deg extension (Lindahl et al, 1969; Scudder, 1980). In fact, to fully extend the knee the quadriceps has to be able to generate 70% of its maximal force whereas only 30% is required to extend the knee to 30 deg (Lieb and Perry, 1968). Therefore, differences in knee extension range of motion between the two groups will have a tremendous impact on the 1RM strength measurements. A knee flexion contracture of 13.8 deg (range: -5 to -35 deg and -3 to -26 in initial and post training measurements respectively) was observed in the LOW mobility group whereas the HIGH mobility group demonstrated a knee flexion contracture of 7.6 deg (range: -3 to -20 deg) in initial muscle testing and 7.5 deg (range: -3 to -20 deg) following the exercise program. Although not significant, the quadriceps muscle strength of the LOW mobility group tended to be tested at larger knee flexion angles, thereby placing the muscle at an advantage. This, in turn, overestimated the measurement of muscle strength in the LOW mobility group and could have impaired the adequate comparison of the initial strength level in the two training groups.
5.2 Effects of Training on Balance

A significant increase of 9.4 points on the Berg was demonstrated in the LOW mobility group following the 12 week exercise program (p=0.0002). This indicates that subjects in this group were able to perform several activities better and possibly added advanced balance skills to their repertoire. Several subjects in the LOW mobility group were able to perform sit-stand transfers and turning 360 deg independently and gained advanced balance skills, such as standing on one foot and placing alternate feet on a stool subsequent to the strengthening program. These results are higher than a previous study documenting an average increase of 5.0 points on the Berg in a group of institutionalized elderly men (Newnham et al, 1995). An additional study investigating the effects of an individualized physical therapy program on the balance of elderly individuals living in residential care facilities reported a 5.6 point increase in the Berg. However, the latter gains occurred over a much shorter time period (5 weeks) (Harada et al, 1995). Differences in the baseline balance level of the subjects may partially account for the differential effect of the exercise regimens on the postural stability of the elderly individuals. The subjects who gained a mean of 5.0-5.6 points (Harada et al, 1995; Newnham et al, 1995) were relatively more stable than the subjects in
the LOW mobility group in the present study prior to the start of the exercise program (Berg: 39.0-39.3 and 29.5 respectively). Subjects in the HIGH mobility group improved by only 6.2% or a mean of 2.3 points on the Berg. The individuals in this group had the highest baseline Berg score (48.6). It therefore appears that subjects with lower pre-training values have greater potential for improvement. Indeed, a high correlation ($r=-0.82$, $P<0.01$) was present between the initial Berg score and the percentage of improvement from T0-T12. This relationship was also apparent when investigating the LOW and HIGH mobility groups separately ($r=-0.83$ and $r=-0.99$, $p<0.01$ respectively).

Overall, the balance level of the subjects in the LOW mobility group improved by 49.3% subsequent to the 12 weeks of exercises. It was noted that 24.5%, 42.6% and 33.0% of the overall improvement in balance (T3-T0) took place during the three time intervals (T1-T0, T2-T1 and T3-T2) respectively. The largest proportion of gains took place over the second month of training. A similar trend was present in the effects of the program on the subjects' knee extension strength illustrated by a 49.2% increase during the second month. This may suggest the possibility of an association.
between muscle strength and balance ability among the elderly. Indeed, adequate lower extremity strength and range of motion are reported to be imperative for the maintenance of a functional balance level (Mills, 1994). Several activities, such as picking up an object from the floor, rising from a chair and completing chair and bed transfers require sufficient knee extension strength for their independent and safe execution. A moderate correlation (r=0.57, p<0.01) between the changes in dynamic quadriceps strength and Berg scores following 12 weeks of training was reported in a previous study conducted at the same institution (Newnham et al, 1995). By comparison, no correlations (r=0.40 and r=0.38, p>0.05) were found in the LOW and HIGH mobility groups partly due to the large group variability and the relatively small sample size in the present study. The presence of neurological impairments (e.g. a previous history of stroke, post-polio syndrome or cerebellar ataxia) limited the impact of the exercise program on the postural stability of several subjects. For example, one subject improved his muscle strength by 286%, but only increased his Berg score by 7% due to the presence of cerebellar ataxia. In this case neurological impairment was a more important factor than muscle weakness in causing postural instability. As a result, the significant increase in the subject's muscle strength did not
lead to clinically significant gains in balance. In contrast, patients with neurological illnesses were excluded from the previous study. It is possible that muscle weakness was the major cause of the reduced balance ability among those individuals. This led to a stronger association between the gains in balance and dynamic muscle strength following the exercise program.

Other studies illustrating the positive effects of strengthening programs on balance include a 9.5% increase in the Tinetti balance subscale (Harada et al, 1995), 14.3% improvement in backward tandem walk (dynamic balance) (Nelson et al, 1994), 22.0% gain in the Roberts balance scale (Mills, 1994) and 20.0-29.8% decrease in body sway (Lord and Castell, 1994) following 5-12 weeks of training given to community dwelling elderly individuals. The ability of an exercise regimen to improve balance is important as poor balance and limited functional performance are known risk factors for falls and further institutionalization (Harada et al, 1995; Nelson et al, 1994; Nevitt et al, 1989; Tinetti et al, 1988, 1994).
5.3 Effects of Training on Mobility Level

The exercise program failed to produce significant changes in the habitual walking speed of the subjects in the LOW mobility group. The average gait velocity increased by 10.0% representing a modest gain of 0.04 m/sec subsequent to the training regimen (Table 5 and 7). Similar results have been reported in recent studies as well (p>0.05) (Harada et al, 1995; Murlow et al, 1994; Newnham et al, 1995). Two other recent studies (Fiatarone et al, 1994; Sauvage et al, 1992), however, reported small (7.8-13.6%), yet statistically significant (p<0.05) gains in walking speed following training. Large group standard deviations have a negative impact on the power of the studies to detect significant changes. Indeed, the group standard deviation in the latter studies was much smaller, namely 0.04-0.05 m/sec, as compared to as high as 0.25m/sec in previous trials (Connelly and Vandervoort, 1995; Harada et al, 1995; Newnham et al, 1995). Although only limited gains in mobility were reported, it is these elderly with physical disability, multiple comorbid conditions and impaired function that should be targeted. Indeed, elderly individuals with impaired mobility are at risk for falls and subsequent fractures (Fiatarone et al, 1994, Tinetti et al, 1988).
The TUG score of the LOW mobility group did not change significantly following the training program. It improved by 11.6%, showing a 4.5 sec decrease following the 3 months training regimen (p>0.05) (Table 5 and 7). Two recent studies investigating the effects of strengthening programs administered to mobility impaired elderly individuals reported no significant change in the TUG score of the subjects following the regimens (Connelly and Vandervoort, 1995; McMurdо and Johnstone, 1995). By comparison, a significant 14.0 sec gain (p<0.05) was demonstrated following 12 weeks of training with institutionalized elderly men (Newnham et al, 1995). The latter study included a small sample (n=12) and excluded patients with a history of stroke or suffering from certain chronic conditions. It is possible that the subjects in that study were carefully selected and may have been more prone to show gains in ambulation. By comparison, subjects included in the present study were more frail and suffered from an average of six comorbid conditions, including neurological and musculoskeletal pathologies. The presence of comorbidity often results in a complex interaction of multiple disease processes preventing large gains from taking place (Sauvage et al, 1992). Furthermore, mobility level is a function of several factors, such as endurance capacity, joint mobility, balance and lower extremity strength.
(Bassey at al., 1977; Bassey et al, 1988, Fiatarone et al, 1990). Although some of these factors are correctable, some may be unmodifiable. Therefore, it is possible that improving the subjects’ lower extremity muscle strength was not enough to bring about significant gains in mobility patterns. In addition, fear of falling and weight-bearing pain due to arthritis are likely to lead to self-imposed restrictions in mobility among the very old (Fiatarone et al, 1994). These factors may have had a negative effect on the subjects’ mobility level leading to high TUG scores and impaired gait patterns.

Secondly, there may be a threshold of muscle strength, below which mobility level is impaired (Buchner and Lateur, 1991; Buchner et al, 1996; Connelly and Vandervoort, 1995; Judge et al, 1993; Rantanen et al, 1996). Therefore, subjects in the present study may have failed to reach that threshold and subsequently demonstrated only modest changes in mobility. Greater strength gains may have been required in order for functional improvements to take place. Newnham et al (1995) reported higher gains in the group mean TUG score (i.e. 14 sec) following training (p<0.005). These subjects were, in fact, 45.7% stronger (1RM: 15.3Kg) than the subjects in the present study at the end of the exercise program.
The exercise program did not have a significant effect on the mobility level of the HIGH mobility group (Table 6 and 7). Similar results were reported in recent studies of high mobility level elderly individuals (Buchner et al, 1996; Judge et al, 1993; Lord et al, 1996; Singh et al, 1997; Skelton et al, 1995; Wolfson et al, 1996). The average gait velocity and TUG score of the members of the HIGH mobility group failed to change significantly following training as it was already relatively high (0.94 m/sec and 13.3 sec respectively) prior to the start of the program. However, the quadricpes strength of this group was low (i.e. 6.6 kg) at baseline. It is, therefore, likely that these subjects were at the threshold whereby small losses in strength may have lead to detrimental losses in mobility. The purpose of training the subjects in the high mobility group can therefore be to preserve their level of mobility as they may be at risk of losing it due to muscle weakness.

In general, there seems to be an association between the baseline test performance and the amount of change in gait patterns. The LOW mobility group tended to show larger gains in walking speed and the TUG test than subjects in the HIGH mobility group. The effects of the intervention on gait velocity were heterogeneous whereby those with initial low walking speeds
showed better gait speeds at re-test, while those with relatively normal gait patterns (>0.9 m/sec) showed little change. However, non-significant correlations (r=-0.60 and -0.43, p>0.05) were found between the baseline walking speed and the percentage of improvement at post-training in the LOW and HIGH mobility groups respectively partly due to the small sample size and the large variability within the two groups. Yet, the subject with the lowest walking speed at baseline (0.20 m/sec) was the one who showed the largest improvement at the end of the exercise program (120%). This trend was also observed in other studies (Judge et al, 1993; Lord et al, 1996).

5.4 Effects of Training on Functional Status

The functional status of the subjects in the LOW and HIGH mobility groups, as measured by the COVS, did not change significantly following the training program (Table 5 and 6). One explanation for these results is the fact that most of the COVS scores at baseline were in the upper tertile (>60.6/91) therefore leading to a ceiling level effect. Indeed, the majority of subjects in the LOW and HIGH mobility groups (77.8 and 85.7% respectively) scored a maximum score on seven and nine items respectively prior to the start of the
training program. This, in turn, limited the ability of the subjects to show improvement subsequent to the exercise regimen. Only one subject scored in the second tertile (i.e.47/91) at baseline. This person showed the largest increase in functional status (19.2%) following the 12 weeks of training.

Limited information is available on the relationship between strength training and functional performance among the elderly. Skelton et al (1995) investigated the effects of a 12 week resistance training program on eight functional tasks, such as functional reach, kneel rise and lifting a shopping bag onto a high surface with a group of community dwelling elderly women. The training group did not show any change in six of the selected functional activities following the exercise regimen. Careful examination of the subjects' performance at baseline revealed that some subjects' pre-training values were at the upper limits and therefore could not show improvement. Mulrow et al (1994) assessed the physical status of nursing home residents following a 4 months physiotherapy program using the Physical Disability Index (PDI). The patient population included individuals suffering from an average of 5 chronic conditions and dependent in at least 2 ADLs. The results of this study indicated that the subjects who had the lowest baseline
physical function (PDI scores in the lowest tertile) had a larger improvement subsequent to the training regimen as compared to those with higher baseline functional status (PDI scores in the middle and upper tertile) (p=0.03). Overall, however, the group average functional status, as measured by the PDI, did not change following the exercise program (p>0.05).

The lack of sensitivity to change due to the ceiling level effect limited the ability of the COVS to document the effects of the exercise program on function. However, subjective accounts given by the primary nurses of the patients reported some improvement in the subjects' functional performance level. A physical status questionnaire (Appendix 2) comprising of questions covering areas such as ambulation, independence in transfers and participation in social activities was filled by the patients' primary nurses during the first week following the exercise program. In general, it was felt that five to seven subjects showed minimal-moderate improvement in walking endurance and the ability to complete transfers independently. Seven subjects showed minimal-moderate improvement in their communication with the hospital staff and participation in social activities.
Subjective improvement in the patients' functional status following exercise regimens has been reported in other recent studies as well. Fisher et al (1991) included a survey of the nursing staff which reported that the nursing home residents were more independent and active following a 6 week training program. Community dwelling women who participated in a 12 week strengthening program reported feeling better able to cope with the demands of daily life (e.g. shopping, use of public transportation) (Skelton et al, 1995). A group of 14 community dwelling women who volunteered to participate in a 16 week total body strength conditioning program reported having greater ease in performing ADLs following the exercise regimen. In conclusion, it seems that high-intensity strengthening programs have the potential to bring about positive changes in functional performance. However, the utilization of appropriate measures of physical status which are sensitive to change and a significant increase in strength may be required before functional improvement can be quantified.

5.5 Effects of training on psychological status

Following 12 weeks of training, the psychological status of the LOW mobility group, as measured by the GDS did not change significantly. A 1.8 point
reduction in the GDS score was documented following an exercise program administered to 20 nursing home residents \((p<0.01)\) (McMurdo and Rennie, 1993). This improvement took place over a period of 7 months while our study actually observed a larger change score (2.1 points) after only 3 months time. The optimal cut off score for the diagnosis of depression is set to be 11 for the GDS (Koeing et al, 1988). Although not statistically significant, the 2.1 group average reduction in the LOW mobility is clinically significant as it shifted the GDS score from 13.0 to 10.9 which is just below the accepted cut off score. A recent study by Singh et al (1997) investigated the effects of a 10 week training program on depressive symptoms of 60-84 year-old elderly diagnosed with minor to major depression. Depression symptoms measured by the GDS, Beck depression inventory and the Hamilton rating scale of depression were reported to decrease by 44.6 \% - 52.1 \% \((p<0.001)\) following the exercise regimen. These results suggest that exercise programs can bring about a significant improvement in the psychological state of depressed elderly individuals.

Further evidence for the positive effect of exercise on the psychological well being of elderly individuals is indicated by statistically significant associations between the regular practise of physical exercise and a lower occurrence of
depressive symptoms in 65-75 year-old elderly (Ruuskanen and Ruoppila, 1995). Also, Gill et al (1997) reported that women with higher levels of activity in their daily lives tend to have greater psychological well being as measured by the General well-being schedule. Increases in opportunity for social interaction and a greater sense of mastery over physical tasks are possible explanations for improved psychological well-being subsequent to physical exercise (North et al, 1990; O'Connor et al, 1993).

The group mean GDS score of the HIGH mobility group did not change significantly subsequent to the exercise program. The subjects' pre-training scores were low, mostly at the 0-4 range, which are well below the cut off for depression. No need for an intervention was therefore warranted. Similar results were documented following a 12 week walking program administered to nursing home residents. The group average changed from a mean pre-training score of 4.4 to 4.8 following the training regimen (p>0.05) (MacRae et al, 1996).
5.6 Limitations of the study

This study used the testing equipment that was available at Ste. Anne's Hospital, therefore permitting the methodology to be conducted by all clinicians. However, as a result the preciseness of the measurements, especially in evaluating lower extremity dynamic strength may have been reduced (affected).

A sample of convenience from the in-patient population of Ste. Anne's Hospital was drawn. The hospital's population is approximately 95% male, who suffer from various chronic disabilities. This may have limited the generalizability of the study to the male, institutionalized patient population.

The sample size of the LOW and HIGH mobility group was relatively small (n=9 and n=7 respectively). This was due to the presence of a high attrition rate (44-56%) in both groups. The advanced age, chronic disability and comorbidity present in this type of patient population led to this high attrition. As a result, the power of the study to detect statistically significant changes in mobility or function following the 3 months exercise program was reduced.
Due to the nature of the group classification procedure (LOW versus HIGH mobility), it was impossible to keep the examiner completely blind. At times it was fairly evident which subjects were mobility impaired and which subjects were not. However, the evaluator was not aware of the objectives or the hypothesis of the study. This, in turn, limited the possible information bias.
6.1 Clinical Implications

Training improved strength in both groups, improved balance in the LOW group and had no effect on mobility in either group. Although we did not expect to improve balance and mobility in the HIGH group, as they were already functioning at high levels, we did expect to improve the performance of the LOW group. However, TUG and average walking speed remained unchanged following training. Part of the problem may have been in patient selection. Although weak, muscle weakness may not have been the primary cause underlying the mobility loss. Other factors, such as neurological or musculoskeletal pathologies may have played a crucial role in their functional deficits.

Strength training programs of the lower extremity muscles seem to be the most appropriate intervention strategy for patients whose principal contributing factor to their functional limitation is related to lower extremity
muscle weakness. Subjects who suffer from severe musculoskeletal disorders, knee flexion contractures and neurological pathologies, such as post-polio syndrome and cerebellar ataxia may not be the most appropriate target population for this type of exercise regimen. The mobility and balance deficits experienced by this type of clientele may not be amenable to change with strength training. For example, one subject in the LOW mobility group who had cerebellar ataxia showed only modest (7%) improvement in the Berg score and minimal change in his mobility level despite a 286% increase in strength post training. Another subject with a previous history of stroke and organic dementia, improved his balance by 11% and failed to demonstrate significant improvement in his mobility despite large gains (118%) in muscle strength.

Cognitive status may also be a limiting factor underlying the effectiveness of an exercise program. Although we excluded individuals with a Folstein mini-mental state score of less than 20, we did not exclude subjects with psychiatric disorders (e.g. schizophrenia, depression; n=5) nor did we evaluate the patients' level of motivation prior to the start of the program. The intensity of training in strength training programs is often regulated by the
1RM test. This measure of strength is based on the level of comprehension and motivation of the subject. Therefore, lack of understanding or motivation experienced by some psychiatric patients may bring about lower values of 1RM and under-estimation of the subject's strength level. The training intensity of such an individual would therefore be sub-optimal leading to limited training effects. The inclusion of subjects with psychiatric disorders in future studies, would therefore require longer periods of familiarization with the testing procedures or using other strength measurement methods, such as the twitch interpolation technique to accurately measure the subjects' muscle strength. Indeed, in our study, an additional 2 weeks of familiarization had to be added prior to the testing of the knee extensor strength in order to ensure the validity and reliability of the measurement taken.

In addition, there seems to be an association between muscle strength and functional ability which contains a threshold level (Buchner and Lateur, 1991; Rantanen et al., 1996). Below the threshold, muscle strength is insufficient to complete a designated task, such as mounting a 25cm step or rising from a 45cm high chair. Above the threshold, muscle strength is sufficient to perform the activity. It is important to recruit subjects whose
strength level is at or below the strength level necessary to achieve the "task of interest" in order to bring about positive training results. Therefore, if the goal of an exercise program is for the subjects to be able to mount a 45 cm step, then those subjects whose strength level is below the threshold for that particular task should be chosen for participation. Also, subjects whose strength level is at the designated threshold level should be trained in order to maintain these functional capabilities. Further research into the identification of such threshold strength levels is required before better patient selection for such exercise programs can take place.

Another important consideration in the planning and implementation of exercise programs is specificity of training. Bearing this in mind, if the primary objective of a regimen is to bring about gains in mobility more emphasis must be placed on mobility type activities during the training session. For example, walking 60 m can become an integral part of the program in order to promote gains in the mobility level of the participants. Educating the patient on the proper use of his/her mobility aid could also be taught and reinforced regularly by the staff.
One has to consider also the length of the training program necessary to achieve significant gains in balance, mobility or functional abilities. Significant gains in the LOW mobility groups' balance ability were distributed over the whole 3 months training period. Subjects increased their Berg score by an average of 2.3, 4.0 and 3.1 points during the three time intervals (i.e 1st, 2nd and 3rd month) of the exercise program (Table 7). Furthermore, significant gains in mobility (7.8-13.6%; p<0.05) (Fiatarone et al., 1994; Newnham et al., 1995; Sauvage et al., 1992) were reported subsequent to training regimens of 10-12 weeks as compared to a 3.8% (p>0.05) improvement following an 8 week long exercise program (Connelly and Vandervoort, 1995). Although the latter gains document minor increases in mobility, it appears that training periods which are longer than 8 weeks would be required before the full impact of strength training on balance and mobility in the elderly can occur.

Finally, sensitivity to change is an important factor when choosing outcome measures. In this study the COVS was used to document the functional status of the participants. Although this test is known to be valid and reliable it was not an appropriate tool for this particular population. The lack of sensitivity
to change due to the ceiling level effect limited the ability of the COVS to document the effects of the exercise program on function. Indeed, the majority of subjects in the LOW and HIGH mobility groups scored a maximal score on between 7 to 9 items (out of 14) prior to the start of the training regimen.

6.2 Research Conclusions

There is growing interest in the effects of exercise on elderly people, although most studies up to date have tended to focus on the highly selected subgroups of the 'young active old' population. Only recently has this work been extended to the more challenging and clinically important groups of frailer old individuals, including those living in long-term institutions.

Muscle weakness is among the main risk factors for falls in the elderly and has the potential to be significantly improved by a single intervention. However, while the effects of exercise on lower extremity muscle strength in older adults is generally accepted, the specific benefits of high-intensity training on balance, gait and functional ability are still largely in question.
Patient selection may be an important factor in studying the impact of exercise regimens on the functional status of the elderly. Older adults often suffer from several illnesses, including neurological and musculoskeletal pathologies. The presence of comorbidity often results in a complex interaction of multiple disease processes preventing large gains from taking place. The goal of training programs with this type of clientele may be to maintain the present level of functioning in order to prevent further declines from taking place.

In addition, the association between strength and functional ability seems to contain a threshold level. Below the threshold, muscle strength is insufficient to accomplish the task of interest. Identifying these threshold levels and targeting subjects with insufficient strength values may lead to clinically significant gains in functional performance following future training programs.
REFERENCES


Lexell, J., Taylor, C.C. and Sjostrom, M. What is the cause of aging atrophy? Total number, size and proportion of different fibre types studied in


APPENDIX 1

EVALUATION OF PAST AND PRESENT PHYSICAL ACTIVITY LEVEL

Name: ___________________ Date: ________________

Compared to others your age and sex would you consider yourself to be:

4. Much more active. / Beaucoup plus actif.
3. Somewhat more active. / Un peu plus actif.
2. About the same. / A peu pres le meme.
1. Somewhat less active. / Un peu moins actif.

In relation to the question above:
Place corresponding number and main activities next to each time period during lifespan. Also note type of work.

Age:
14-30 _____ ________________________________
31-50 _____ ________________________________
51-retirement _____ __________________________
Retirement-institutionalized _____ _________________________
Present _____ ________________________________
APPENDIX 2
CONSENT FORM

McGill University
School of Physical and Occupational Therapy
Consent To Participate in a Research Study on Exercise

I ___________________________ consent to participate in this research study.

(a) Purpose and Design of the Study

The purpose of this study is to investigate the effects of strengthening exercises on mobility during activities of daily living. I have been told that I will be evaluated four times, once prior to the start of the intervention, as well as three times during the 12 week training period. These sessions will last approximately 1 hour each and will involve the testing of my leg strength as well as my performance in basic mobility functions such as getting up from a chair and walking a short distance. I will be asked as well to respond to various questionnaires about past and present physical activity level and overall function.

I am aware that I will be involved in an exercise program that will be held 3 x week, for 12 weeks. Each session will last 45-60 minutes and will involve a series of exercises designed to strengthen my legs and improve my mobility.

(b) Disadvantages of Participation in this Study

The main disadvantage will be the time commitment on my part. I will be required to be evaluated 4 times and attend an exercise program 3x week for a 12 week period. I am aware that there may be some mild discomfort at the start of the exercise program.
APPENDIX 2 CONT'D

(c) Advantages of Participation in this Study

Although there are no monetary or personal benefits to be gained from participating in this study, the results from this research will contribute to the understanding of how exercise affects strength and functional performance in the older adult.

(d) Enquiries Concerning this Study

I understand that any inquiries that I may have will be answered by Miss Orly Ardman of the School of Physical and Occupational Therapy, McGill University, 398-5589.

(e) Withdrawal from the Study

I understand that my participation in this study is voluntary and that I may withdraw at any time, without prejudice to any further treatment in the Physiotherapy Department.

(f) Permission to Use Information

I give the investigator(s) permission to keep and utilize the information from the study as long as my identity is kept confidential.

Dated the _______ day of _______________, 19______.

Signed: ________________________________

Witness: ________________________________

I, Orly Ardman, hereby certify that we have explained to the above-mentioned subject the nature of the study, the known risks involved in participating in the study and that he has the option of withdrawing from the study at any time.

Signed: ________________________________