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LOWER EXTREMITY STRENGTH TRAINING

TO DECREASE FALLS IN THE ELDERLY

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by

Kelly L. Spadolini
Bachelor of Science in Physical Therapy
University of North Dakota, 1996

An Independent Study

Submitted to the Graduate Faculty of the

Department of Physical Therapy

School of Medicine

University of North Dakota

in partial fulfillment of the requirements

for the degree of

Master of Physical Therapy

Grand Forks, North Dakota
May
1997

This Independent Study, submitted by Kelly L. Spadolini in partial fulfillment of the requirements for the Degree of Master of Physical Therapy from the University of North Dakota, has been read by the Faculty Preceptor, Advisor, and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

(Faculty Preceptor)

(Graduate School Advisor)

(Chairperson, Physical Therapy)

PERMISSION

Title	Lower Extremity Strength Training to Decrease Falls in the Elderly.
Department	Physical Therapy
Degree	Master of Physical Therapy

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ABSTRACT

As the elderly population grows, the health care needs of people over the age of sixty-five will dominate the medical profession. Methods of prevention of health problems are key to providing the optimal medical care. Falling has been reported as the most prevalent means of injury in older people. One third of all seniors living in the community and one half of those residing in nursing homes fall each year. Research indicates that elderly people who fall have weaker lower extremity strength than elderly people who do not fall. As a result, some clinicians have incorporated strengthening regiments into fall prevention programs created for the elderly.

The purpose of this independent study is to provide a comprehensive literature review of the current use and efficacy of strength training to reduce the muscular deficits and subsequent falls that occur in the elderly population. Recommendations for lower extremity strength training for future fall intervention programs will also be included.

CHAPTER I

INTRODUCTION

Currently, 12% of the United States population is 65 years of age and older with this proportion expected to increase to over 20% by the year 2040.[1] Of the present elderly population one third of those living in the community and one half of those residing in nursing homes fall each year.[2] One in 40 of these falls leads to hospitalization with one percent resulting in hip fractures that cost the United States $7 to $12 billion in hospital expenses annually.[2,3] Not only are these falls costly, but they often result in diminished functional status, loss of independence and increased need for physical assistance at home and within the nursing facility.[1-6]

The etiology of falls in the elderly population has attracted much research. Several studies have identified a variety of environmental and medical factors that increase the risk of falls in the elderly. Included in these factors are diminished proprioception, decreased reaction time, loss of hearing, altered vision, gait changes, intake of multiple medications, and muscle weakness. Many specific medical conditions also increase the risk of falling, such as cerebral vascular accidents, Parkinson's disease, arthritis, vertigo, osteoporosis, and orthostatic hypotension.[3-7] Of these risk factors, the loss of lower extremity strength has been documented as a cause of falls in as many as 36% of all cases.[2,3] However, muscle weakness has also been cited as a significant component of elderly falls that can be reversed.[7-11]

In order to effectively prevent falls that occur as a result of muscle weakness it is essential to first understand the natural decline in muscle mass and strength that occurs with age in both sedimentary and, to a lesser extent, in active individuals.[12-13] Research suggests that there is a loss of at least 30-40% of muscle mass by the age of 80, with muscle strength and fiber numbers falling by similar proportions.[6,9,14] The biological, pathological and functional causes for these changes will be discussed in detail.[15-19]

Once there is a clear understanding of the muscular deficits and their causes, the reversibility of these deficits can be demonstrated through strength training. Progressive resistance exercise using isotonic, isometric and isokinetic exercises have all shown marked improvements in muscle strength, muscle mass, and individual muscle fiber cross sectional area in several studies with elderly subjects.[20-29] In some cases the muscle deficits could be completely reversed using as few as 6 weeks of resistance training.[29,30]

With the beneficial results found in strength training in the elderly it would make sense that many clinicians would incorporate resistance exercise into fall prevention programs, using the improved lower extremity strength to decrease the risk of falls.[31,32] However, research on the use of strengthening to prevent falls in the elderly is limited. Nonetheless, the few fall prevention research programs that incorporate muscle strengthening have shown several positive results.[32-37] The purpose of this independent study is to provide a comprehensive literature review of the current use and efficacy of strength training to reduce the muscular deficits and subsequent falls that occur in the elderly population. Recommendations for lower extremity strength training for future fall intervention programs will also be presented.

CHAPTER II

THE CHANGES IN MUSCLE FUNCTION WITH AGE

To effectively prevent falls that result from muscle weakness, the muscle changes that occur with aging should be clearly understood. This chapter will provide a complete review of the muscular changes in the elderly, as well as the causes and the consequences of these changes.

Muscle weakness in the elderly is a multifactorial phenomenon that is often linked to the high prevalence of falls in this population. Several recent controlled studies have identified lower extremity muscle weakness as one of many important risk factors for falls in the elderly.[2,3,38-42] Specifically, research reveals that elderly people who fall have significantly weaker dorsiflexion, plantar flexion, knee flexion, and knee extension than elderly people who did not have a history of falls.[11]

The decline in muscle strength with aging is well documented.[14,43-47] Several studies demonstrate a decline in muscle strength of up to 40% by the age of 80.[6,9,14,43-45] This loss in strength is particularly prominent in the lower extremities.[17] For instance, Aniansson et al[14] found that from the age of 70 to 75 quadriceps strength declines 9% to 27% for men and 14% to 25% for women while hand grip strength is remarkably well preserved in both sexes with no significant decline in strength observed until 79 years of age. Davis and his colleagues[46] compared the strength of the gastrocnemius and soleus muscles between elderly and young men and women and found that plantar flexion strength is 38% and 28% weaker in elderly men and women, respectively, than in their younger counterparts. In a similar study, Vandervoort and McComas[47] observed a decline in the strength of plantar flexors and dorsiflexors of healthy men and women beginning at as early as 35 years of age and continuing to decline by 15% per decade.

Multiple causes account for the muscle weakness that accompanies aging. The remainder of this chapter will identify the biological, pathological and functional causes of muscle weakness in the elderly.

Biological Causes

There are several biological causes for the decline in muscle function in the elderly. Skeletal muscle consists of three types of muscle fibers: type I (slow-twitch, oxidative), type IIa (fast-twitch, oxidative-glycolytic), and type IIb (fast-twitch, glycolytic). Endurance and slow contraction velocity are functional characteristics of type I muscle fibers. High force and speed of contraction are functional characteristics of type II muscle fibers.[48] Most of the muscles in the human body have approximately equal proportions of slow- and fast-twitch muscle fibers. However, as skeletal muscle ages, there is a preferential atrophy of fast-twitch muscle fibers and a subsequent increase in slow-twitch fibers.[15,16,49,50]

There is some controversy in the research regarding the actual percentage of type II muscle fibers that are loss during the aging process.

Brooks and his colleagues[44] found only a minimal change in the number or size of any of the three fiber types in elderly subjects under 70 years of age. However, Grimby et al[51] found the numbers of type II muscle fibers decrease by 15-20% and Larsson[52] identified a decline of as much as 40% after the age of 70. The loss of type II muscle fibers was observed at as early as 25 years of age and deteriorated thereafter in a study by Porter and his collegeagues.[49] Although the research numbers vary it is generally believed that there is a significant loss in type II muscle fibers with aging.[17]

The loss of type II, fast twitch, muscle fibers consequently effects elderly muscle function in several ways. Technically, the decrease in fast-twitch fibers in the elderly is seen in a significant increase in both time to peak tension, and the time to relaxation following contraction,[46-47] which result in a reduced rate of force development in the muscle and diminished ability to accelerate movements.[53] Clinically, elderly subjects have slower reaction times, weaker contractions and require longer to recover from activity.[50]

As a result of the selective loss of type II muscle fibers there is an increase in the percentage of type I fibers of up to 40% between 20 and 30 years of age and up to 55% between 60 and 65 years of age.[54] The increase in type I fibers with age is not only a result of the selective loss of type II fibers but also is caused by the reinnervation of denervated type II motor units by type I motor units.[44,50] Research suggests there are specific morphological aspects of faster motor nerves (type II) that results in the preferential degeneration of these nerves and the subsequent denervation of type II muscle fibers.[55] According to

Brooks and Faulkner[44] there is a grouping of slow-twitch (type I) muscle fibers that occurs in elderly muscle that results from this denervation of fast-twitch (type II) muscle fibers with reinnervation by axonal sprouting from an adjacent innervated slow-twitch motor unit. Furthermore, their research stated that this motor unit "remodeling" can explain much of the muscle atrophy and strength decline that accompanies aging.

Presumably the type II muscle fibers that are not reinnervated undergo atrophy, thus the total number of motor units also declines with age.[16,49] Moreover, the remaining motor units are much larger and predominantly slow twitch due to the axonal sprouting.[44] Campbell and his colleagues[56] found a 75% decline in the total number of motor units after 70 years of age in some skeletal muscles. Tomlinson[57] found the number of motor units reduced up to 50% in the lumbosacral cord in subjects over 60 years of age. This change in motor unit size and number decreases coordination, speed of contraction, overall muscle mass, and directly effects functional patterns in the elderly.[16,44]

The significant loss of lean muscle mass with aging has been identified as another factor that alters the function of elderly muscle. A 30% to 40% decline in lean muscle mass is seen in elderly subjects by the age of 80.[6,9,14] Research suggests this loss primarily effects the proximal muscle of the lower extremities.[50] Lexell et al[53] focused specifically on the vastus lateralis of previously healthy men between 15 and 83 years of age and found an average loss of 40% of muscle mass by 80. This mass reduction began as early as 25 years with a 10% loss at the age of 50.

The decrease in lean muscle mass is associated with a decreased total protein and nitrogen concentration combined with an increase in connective tissue and fat with aging.[50] Rice and his colleagues[58] document an increase in nonmuscle tissue (fat and connective tissue) within elderly muscle of 27%, 45%, and 81%, respectively, for arm flexors, arm extensor and plantar flexors of the elderly. Overend et al[59] also report an increase in nonmuscle tissue of 59% in the quadriceps and 127% in the hamstrings of elderly men.

Age related infiltration of fat and connective tissue appear to result in the reduction of muscle contractile tissue more so than the actual reduction in muscle volume and cross sectional area.[50] This increase in fat and connective tissue can disrupt the normal orientation of the muscle myofilaments. Such composition changes as well as the loss of muscle fibers cause a notable decrease in maximal tension generated by contracting muscle which is clinically manifested in muscle weakness, slowness, and incoordination.[17]

There are also several biological causes that, although are not as well documented, are reported to contribute to the deficits in muscle strength in the elderly. First, the cardiovascular system loses efficiency with age and consequently various essential proteins are not delivered to muscles in the same quantity as with younger adults. Second, the selectively permeable membrane of muscle cells appears to decrease in efficiency particularly reducing the entry of potassium ions in aging muscle resulting in decreased maximum force of contraction, fatigue and lethargy of muscles. Third, nutritional requirements of muscle are also altered as people age. Aging may change nutrient intake, increase the need for specific nutrients and interfere with the absorption, storage and utilization of specific nutrients.[16]

Research has both studied nutrients that enhance muscle as well as the consequences of inadequate nutrient intake. Vitamin C enhances muscular contraction and delays onset of fatigue.[60] Zinc, which is often deficient in the elderly population, functions in muscle growth and enhancing the strength of contractions.[61,62] Elderly subjects with specific nutrient deficits of vitamin D, magnesium, zinc, and protein may exhibit impaired muscle function.[12] Inadequate protein intake alone can result in; decreased muscle fiber area, selective fiber atrophy, disorganization of myofibrils, decreased oxidative enzyme capacity, glycogen depletion, electrolyte imbalance, decreased strength and prolonged reaction time.[18] Undernutrition (a mild form of malnutrition that is not to the degree that is considered pathological) is a common preventable and reversible condition associated with muscle weakness in the elderly population. Clearly, there are many naturally occurring alterations in muscle function due to biological causes.

Pathological Causes

In addition to the multiple biological causes of muscle weakness, there are numerous strength altering diseases that affect the elderly and can contribute to muscle weakness. For instance, several endocrinologic conditions can result in generalized muscle weakness including hypothyroidism, hyperthyroidism, male hypogonadism, diabetes, Cushing's disease, and Addison's disease.[3,63] Approximately 10% of individuals over 65 have diabetes and many of these individuals experience lower extremity muscle weakness secondary to peripheral neuropathy. In addition, hypothyroidism is seen in 2% to 5% of people over 65 years of age and leads to impaired energy metabolism within the muscle fiber and a decrease in contractile force. This disease manifests itself in proximal muscle weakness, fatigue, slowing of movements, stiffness, myalgias, cramps and occasionally enlargement of the quadriceps muscles due to myoedema.[63]

There are also several electrolyte and mineral alterations that can manifest in muscle weakness, including but not limited to; hypophosphatemia, hypokalemia, hyperkalemia, and hypercalcemia.[3] Of these, hypokalemia is the most common cause of electrolyte myopathy in the elderly and often results in slowly developing muscle weakness that begins in the legs and, in severe cases, spreads to the arms, trunk and neck.[63]

Dermatomyositis, polymyositis, anemia, congestive heart failure, and chronic infections such as tuberculosis are often associated with muscle weakness.[16] Specifically, dermatomyositis, an autoimmune connective tissue disease, affects the membranes and vascular endothelium of skeletal muscle fibers resulting in proximal limb muscle weakness in many elderly individuals. Polymyositis, another autoimmune connective tissue disease, that primarily affects 45- to 65-year-olds. This disease causes damage to muscle fibers through cytotoxic lymphocytes and results in muscle weakness usually occurring in the hips and thighs causing difficulty in arising from squatting, in kneeling and in climbing or descending stairs.[63]

Several other pathological factors can also contribute to muscle weakness in the elderly. Malnutrition, that is seen in 17% of community dwelling elderly and up to 59% of institutionalized elderly, even of a mild degree can result in muscle weakness.[16,18,63,64] Polymyalgia Reumatica is also seen in about 1.5% of elderly over 65 and is characterized by pain, muscle weakness, and stiffness in the proximal muscle groups.[16,63] Alcoholism, a condition seen in 2% to 5% of elderly men and 1% of elderly women, can result in alcohol myopathy that inevitably causes a decline in muscle strength for these individuals.[3,63]

Muscle function in the elderly is not only affected by the cumulative effects of multiple acute and chronic illnesses but also by their pharmacologic interventions. For example, the chronic use of diuretics for cardiovascular disease is associated with the depletion of skeletal muscle electrolytes and attribute to muscle weakness. Similarly, corticosteriods have been found to exert catabolic effects on muscle tissues leading to proximal muscle weakness and atrophy if used chronically as in chronic obstructive pulmonary disease (COPD) and many rheumatologic diseases.[18] In addition, psychotropic drugs, which are prescribed to 50% of nursing home residents in the United States, have consistently been associated with quadriceps weakness, impaired gait and increased fall risk.[5] It is essential to recognize the pathological effects that disease and medications can have on the muscle function of the elderly.

Functional Causes

Along with the biological and pathological causes, there are also several functional causes that contribute to the decline in elderly muscle strength and function. Research has proved that muscle strength declines with inactivity.[65-68] Furthermore, immobility and decreased activity has been shown to predispose elderly persons to significant functional decline.[17] Harper and Lyles[67] reported a loss of 1% to 3% of muscle strength per day of bed rest and as much as a 10% to 15% loss per week. Muller[68] also found that immobility persisting for two months can result in atrophy of skeletal muscle mass to half its original size. Similar results are found by Corcoran et al[66] but reveal that larger muscles are more affected than smaller muscles and that leg musculature lose strength twice as fast as arm musculature. Halar and his colleagues[67] specifically found that bed rest is most detrimental on the quadriceps, back extensors, gastrocnemius, soleus, anterior tibialis and to a lesser extent the biceps and shoulder muscles.

Inactivity and muscle disuse also produces histochemical changes in skeletal muscle of the elderly. Eichelberger et al[69] found inactivity leads to a decreased oxidative capacity of muscle mitochondria, a decreased tolerance to oxygen debt, an earlier and longer accumulation of lactic acid, a fiber degeneration and an increase in the proportion of fat and fibrous tissue in muscle. All these changes affect the normal function of skeletal muscle.

Numerous studies show that loss of muscle strength is, at least in part, because of a decrease in activity level in elderly subjects.[16,14,66] Approximately 35% of community dwelling elderly over 65 describe themselves as being limited in some type of daily activity and only 29% of elderly over 65 report doing any regular exercise, including walking.[63] Muscles that continue to be used regularly in activities of daily living such as the hand musculature tend to maintain strength throughout aging.[14] However, those muscle groups that lack the fast forceful movements in daily living consequently fail to optimally recruit motor units which results in altered muscle function and decreased muscle strength.[16] Inactivity and immobility tend to be common in elderly due not only to lifestyle changes but also to the multiple acute and chronic illnesses endured by this population.[66]

Another serious contributing factor in falls in the elderly is the 'fear of falling'.[70] Many elderly people, whether they have experienced a fall or not, have such a concern about falling that they tend to avoid activities that they remain physically capable of performing.[70,71] About 40% of elderly have this fear of falling and about 20% of elderly avoid activities such as shopping and cleaning because of this fear.[63] The fear of falling leads to and is a part of a debilitating post-fall syndrome that is characterized by hesitancy, tentativeness, and loss of confidence, mobility and independence.[70-72] Elderly who fear falling limit their activities which in turn contributes to further deterioration of their physical function.[70] The result is a viscious cycle of the fear of falling causing decreased activity, which in turn causes decreased muscle function leading to increased risk of falling and thus greater fear.[65-68,72]

In summary, there are numerous factors that contribute to the decline in muscle function as people age. Although some of the biological and pathological causes appear to be inevitable, it is a mistake to believe muscle weakness cannot be reversed in many cases. Proper nutrition and increased activity level have both been shown to improve the functional capacity of aging muscle.[20,69,73] Improving muscle strength in the elderly should decrease the risk of falling due to muscle weakness as well as improve confidence levels and decrease the fear of falling. The next chapter will review the role of strength training to prevent or reverse strength loss in the elderly.

CHAPTER III

THE EFFECTS OF STRENGTH TRAINING ON MUSCLE FUNCTION IN THE ELDERLY

To effectively prevent falls due to lower extremity muscle weakness in the elderly, the deficits in muscle function must be reversed. Strength training has been shown to improve muscle function at all ages studied, however research using strength training on the elderly is very limited.[16,73] In the current literature, the majority of strength training studies in the elderly use healthy, active, community dwelling men.[20-29] There are relatively few strengthening studies that focus on weak, institutionalized and/or very old subjects, which ironically are the individuals at the highest risk of falls and who may potentially benefit most from strength training.[18] Nonetheless, the research that has been published clearly demonstrates that elderly men and women, even up to 90 years, maintain the ability to increase their strength.[20-31,43] This chapter will provide a detailed review of the effect of these strength training studies on muscle strength, muscle mass, and neuromuscular function in healthy community dwelling elderly and in frail and institutionalized elderly.

Improvements in Healthy, Community Dwelling Elderly

Several studies have used strength training regimes to improve muscle strength and muscle hypertrophy in community dwelling, healthy elderly subjects.[20,22,23,26,27,29] Frontere and his colleagues[20] found the most impressive results using isokinetic strength training on 12 healthy elderly male subjects between 60 and 72 years of age. The training program lasted 12 weeks with three daily sessions performed three times per week. Lower extremity strength increases of up to 227%, midthigh muscle mass increases of 4.8%, and type I and type II muscle fiber cross-sectional area (CSA) increases of 33.5% and 27.6%, respectively were observed. This study was concentrated on the lower extremity muscles but significant improvements have also been seen in other studies using 12 weeks of isokinetic strength training on the upper extremity muscles of elderly subjects.[23,26]

Larsonn et al[27] also found muscular improvements using isotonic strength training on six healthy men (56-65 years) that trained the quadriceps muscles twice a week for 15 weeks. The intensity and frequency of the exercise sessions were much less that Frontere's[20] research, but quadriceps strength and type II CSA still increased moderately following the program.

More significantly, Charette and her colleagues[22] found 115% improvements in quadriceps muscle strength and 20% increase in type II CSA in 27 elderly women (between 64-84 years) using only 12 weeks of isotonic strength training performed three times a week. And, Perkins and Kaiser[29] showed similar results using both isotonic and isometric strengthening in 20 elderly male and female subjects three times a week for only six weeks. In addition, the strength gains of this study remained five months following the completion supervised program.

Muscle strength and muscle hypertrophy are not the only improvements seen with strength training in the elderly. Sipila et al[21] found significant decreases in intramuscular fat in the lower extremities of 16 elderly women following 18 weeks of isotonic strength training. This study also tested women using only aerobic activity but the same improvements were not observed (there was insignificant muscle hypertrophy and negligible decrease in intramuscular fat). This study is important because research shows that decreases in intramuscular fat may improve the maximal tension and coordination of muscle contractions.[17]

Moritani and deVries[24] also found an improvement in the neural activation of muscle. Simply, they observed that elderly subjects primarily improve muscle strength by increasing the maximal muscle activation level through greater facilitation and/or less inhibition of motor nerves rather than through muscle hypertrophy. Although many other studies have proved that muscle strength increases result from both muscle hypertrophy and improved neural activation, this study significantly shows elderly subjects had strength gains with no observed hypertrophy, while younger subjects did not.

Improvements in Frail and Institutionalized Elderly

Since this independent study focuses on preventing falls in the elderly that occur from lower extremity muscle weakness, the research that shows improvements in strength in the population at highest risk of falling is imperative. Frail and institutionalized elderly make up 61% of the falls that are reported each year.[74] Very little research has used strength training on weak nursing home residents, but the few studies that have been published show positive results.[30-31,43]

Fisher and her colleagues[30] found benefits using six weeks of isometric and isotonic strength training on 14 nursing home residents (aged 60 to 90 years) who had markedly deteriorated muscle function. Seventy-five percent of subjects showed improved quadriceps function with endurance, strength and speed of contraction increasing 35%, 15% and 10%, respectively. In addition, improvements in spontaneous activity and decreased dependence on nursing staff remained for four months following the training program. At the completion of the study, the authors concluded that a greater number of benefits may be possible with the use of a longer and higher intensity regime.

Fiatarone et al[43] implemented a longer and higher intensity program than to the one Fisher[30] suggested. They used an 8-week isotonic strengthening program on 10 frail, institutionalized subjects averaging 90 years of age. The subjects performed three set of quadriceps exercises three times a week and improved the quadriceps strength by 174%. Improvements were also reported in midthigh muscle mass and mean tandem gait speed following the training. This study is important because it not only shows significant improvements in strength and muscle mass but it also shows carryover into functional activity (walking).

Sauvage and his colleagues[21] also show functional benefits following 12 weeks of isotonic strength training and stationary cycling on eight deconditioned nursing home residents who displayed poor balance and lower extremity weakness. Ten outcome measures were assessed before and after the program and of those ten the strengthening group revealed significant improvements in the Tinetti mobility scores, quadriceps strength, lower extremity muscle endurance, left stride length and gait velocity. The authors concluded that appropriately designed strength training can result in significant improvements in clinical mobility in frail nursing home residents.

There are number of studies that use other forms of exercise to improve lower extremity muscle strength and in turn to prevent falls.[8,75-78] Although these studies have shown increases in muscle strength in the elderly, the improvements are not as great as those found with strength training.[28] It is important to note that aerobic activities such as walking, jogging, and cycling are beneficial to elderly individuals.[8] These activities increase the overall activity level and improve the cardiovascular endurance that is often so low in the elderly that even healthy individuals over 65 often report difficulties carrying out activities of daily living without fatigue.[63] In addition, aerobic activities have been shown to significantly improve quadriceps strength, reaction time, postural sway, speed of muscular contraction, walking velocity, standing balance and flexibility of the hip and trunk in elderly subjects.[72,76,77] Aerobic activities can also be used to maintain gains achieved using strength training for up to one year following the resistance training program.[78] Although the research on these other forms of exercise is important to the elderly population, the details of these studies, however, are outside the realm of this paper.

Clearly, isokinetic, isotonic and isometric strength training can all produce muscle function improvements in the elderly.[20-31,43] The most impressive results were found using isokinetic exercises; however, isokinetic equipment is expensive and complicated and in most cases it is not a practical means of incorporating strength training into elderly individuals lifestyle.[20] Isotonic and isometric programs were similarly effective in producing strength gains, hypertrophy, improved neural activation and decreased intramuscular fat in elderly volunteers. [21,22,24,27,29] Even the frail and institutionalized were able to make significant improvements in as little as six weeks and were able to functionally benefit for up to four months following one isotonic/isokinetic program.[24] Moreover, isotonic and isometric strengthening exercises can be modified into functional exercise programs to specifically improve strength for activities of daily living.[79]

Although this chapter convincingly shows that elderly subjects, even those at highest risk of falling, maintain the ability to reverse muscle function deficits through strength training, there is little research that significantly relates these muscular improvements in functional activity. When incorporating strength exercise into programs for fall prevention it is imperative to insure that the activities that are employed in fact will decrease the participants risk of falling. The next chapter will review the literature published on incorporating muscle strengthening into fall prevention and will provide guidelines for future fall prevention programs.

CHAPTER IV

PREVENTING ELDERLY FALLS WITH STRENGTH TRAINING

In the previous two chapters the muscle deficits that occur with aging and the reversibility of these deficits using strength training were thoroughly discussed. This chapter will review the current research that uses strength training to prevent elderly falls, including the limitations of this research and recommendations for future fall intervention.

As shown, muscle strength clearly declines with age and significantly contributes to falls in the elderly. In addition, it is well documented that strength training in this population can increase muscle size, strength and neural activation. It is reasonable to assume that improved neuromuscular function achieved through exercise would reduce falls in the elderly, however this has not been conclusively demonstrated in the literature.[2] If falls occur at least in part to lower extremity muscle weakness then strengthening targeted to improve this deficit should clearly result in fewer falls.[32]

Current Research

There is very limited research that uses muscle strengthening for fall prevention in the elderly. The best documentation that uses exercise to intervene in falls is published by the Frailty and Injuries: Cooperative Studies of Intervention Techniques (FICSIT). The FICSIT trials consisted of seven independent, randomized, controlled clinical experiments that assessed intervention efficacy in reducing falls and frailty in elderly patients. The overall purpose of this research was to determine if short-term exercise reduces falls and fall-related injuries in the elderly. All seven of the FICSIT trials included 10 to 36 weeks of some type of exercise and at least one year of follow-up to record the occurance of falls. Of these seven, however, only five sites used resistance training as part of their studies.[32] These five studies will be reviewed in detailed in this chapter.

Tinetti and his colleagues[33] studied 300 subjects who were 70 years of age and older. All subjects were cognitively intact, not terminally ill, not physically active and possessed at least one fall risk factor. Forty-three percent of the subjects reported falling within the previous year. The authors compared the effectiveness of usual care plus social visits (n=150) and targeted risk intervention strategy (n=150) in reducing falls among at risk community elderly persons. The intervention strategy included medication adjustments, behavioral change recommendations, education and home-based exercise regimens targeting the individual identified risk factors. When muscle weakness was identified in the subjects, exercises were prescribed according to the individual deficits of each subject. The strengthening exercises were not described in the study except to note that progress was made by advancing the resistance of theraputty and theraband. The researchers also used four levels of balance exercises with some subjects to improve lower extremity strength and coordination including; standing toe raises, sidestepping, one leg stance and sitting marching. Fall occurance was the primary outcome measured in this trial. The subjects were followed for 12 months. The reported mean number of fall events per subject was 1.39 for the control group who received the social visits and 1.07 for the subjects who underwent the intervention strategy.[32] Risk intervention was shown to significantly reduce falls.

Buchner et al[34] compared the effects of three 6-month exercise interventions (endurance training, strength training, or combined strength and endurance training) on aerobic capacity, strength, gait, balance and fall occurance. The study used 100 subjects between 68 and 85 years that demonstrated leg weakness, impaired gait and resided in the community. Twenty-three percent of the subjects reported falling in the previous year. The strength training group (n=25) were either trained on Cybex or Nautilus isokinetic equipment and included strengthening exercises for the gluteus muscles, quadriceps, gastrocnemius, soleus, hamstring, hip abductors and adductors, internal and external obliques, pectoralis major, anterior deltoid, biceps, triceps, deltoids, trapezius, and ankle planterflexors, dorsiflexors, inverters, and everters. The subjects underwent three weeks of 10 repetitions of 50% of one repetition maximum (1RM) on each muscle group and progressed by adding second set of 10 repetitions of 75-80% of 1RM at week four. Subjects were followed for an average of 18 months and the reported mean number of fall events per subject was 1.60 for the control group, .68 for the strength trained group, .80 for the endurance trained group and 1.48 for the combination trained group.[32] Strength training alone showed the greatest benefits in decreasing falls in this trial.

Mulrow et al[35] studied 195 frail nursing home residents, averaging 81 years of age, who were functionally dependent in two or more activities of daily living but who were not severely cognitively impaired. Fifty-four percent of the subjects reported falling within the previous year. The subjects were randomly divided into control group and trial group. The trial group underwent four months of individualized physical therapy. Subjects met with physical therapist three times a week to perform functional activity and general conditioning (including resistance, flexibility and balance training). The exercises were individually tailored to the subjects level of physical and functional disability. Follow-up on fall incidents was continued from 18 to 32 months after the program. Interestingly, the reported number of fall events per subject was not significantly different between the control group and the treatment group of this trial. The authors speculate that these results were due to the severe frailty and the multiple comorbid conditions of the subjects studied and believe more beneficial results could be observed with less chronically involved nursing home residents.[32]

In addition, Fiatarone and her colleages[36] performed nursing home-based intervention to improve muscle strength through progressive resistance exercise training of the lower extremities and/or using multi-nutrient supplement. The study used 100 chronically institutionalized subjects ranging in age from 70 to 100 and who were at high risk of falling. Sixty-six percent of the subjects reported falling within the previous year. For 10 weeks, the subjects divided into four groups: (1) high intensity progressive resistance training of hip and knee extensors three days per week, (2) multi-nutrient supplement, (3) combination of both training and supplement and (4) control. Outcome measurements of falls were obtained for 1½ years up to 4 years following the program. The reported mean number of falls per subject were 2.77 for the control group, 2.32 for the resistance trained group, 2.92 for the combined group and the supplement group was excluded from these results. The authors believe that the nutritional supplement provided in the combined group may not have been of sufficient magnitude or duration to augment muscle function.[32] Nonetheless, the falls were reported least in the resistance trained group of this trial.

Finally, Wolfson et al[37] studied 109 community dwelling elderly subjects over 75 years of age. The study intended to see if (1) balance training alone; or (2) strength training alone would be capable of significantly improving balance, gait, and functional mobility; and, that (3) combined program of balance and strength training would be more effective than either approach alone. The subjects underwent 45 minute sessions three times week for three months. The sessions included home-based Tai Chi training (an ancient Chinese discipline of meditative movements practiced as a system of balance exercise) and strength training of the hip abductors, hip extensors, knee flexors, knee extensors, ankle planterflexors and ankle dorsiflexors. Thirty-one percent of the subjects reported falling within the previous year. Follow-up of one year was recorded and the reported mean number of fall events per subject was 1.22 for the control group, .82 for the resistance group, .82 for the balance group and 1.07 for the combination group. The authors attribute the insignificant higher incidence of falls that occurred in the combination group to the high variability in response to training. The strength trained and balance trained groups showed the best decreases in the reported number of falls.[32]

Limitations of Research

The overall analysis of the FICSIT trials concluded that exercise does play significant role in reducing falls in the elderly. However, the results of these five trials raise some important questions regarding future physical therapy treatment. Many of the studies showed that falls were lowest in the strength or balance trained groups but were actually increased in the combination trained groups. However, the studies that revealed this result were based in nursing homes and tested elderly subjects that were severely frail and suffered multiple comorbid conditions. The community based studies found more beneficial results using combined training regimes. Therefore, it would be a mistake to assume the results found in the chronically involved nursing home residents means that combining different forms of exercise into treatment plans would be detrimental to all elderly patients.

Unfortunately, the FICSIT trials were five separate, independent studies that included specific information on falls for the FICSIT analysis but did not necessarily include that information as part of their individual outcome measures. As a result many of the confusing findings on combination training were not explained. In addition, conclusions from this analysis regarding the effects of specific types of exercise (e.g., balance, resistance) must be guarded by the fact that many of these were tested in combination with other types and/or nonexercise interventions therefore presenting difficulties in identifying the success of any specific type of exercise.[32] Another major limitation to the FICSIT trials lies in the limited description given of the strength exercises and the progression used in the studies making the studies difficult to repeat and document.[33-37]

Not including the FICSIT study, the current research on fall prevention in the elderly is extremely limited. Much of the research available on elderly falls results from studies that target nursing personnel and discuss the use of physical restraints (bed rails, poseys, belts, and harnesses) to prevent falling.[17] Ironically, other research suggests that the use of such restraints actually increase the risk of falls in the elderly.[79-81] Physical restraints often lead to immobility and inactivity in the patients that use them, further targeting them for muscle weakness and subsequent falls.[32,65-68]

It is important to note that there are several studies that claim their exercise programs help to prevent falls, but which do not measure falls prior to or following their strengthening programs.[8,10,32,75-76] Many of these studies measure the effects of physical activity, some including strength training, on functional outcomes such as reaction time, postural sway, and balance tasks in the elderly but none of them include the occurance of falls.[8,10,75,76] For this reason, these studies were not included in this review of fall interventions using muscle strengthening.

The exclusion of functional exercise programs is another significant limitation in the available research on fall intervention. Specificity of exercise implies that the muscle groups strengthened in resistance exercise program must be the same muscles that require strength during the specific functional activity you intend to improve. Specificity in training can also relate to the speed at which an exercise is performed, the type of muscle contraction elicited, the intensity of the exercise or the part of the range in which the exercise is performed.[82] All these variables must match the requirements and demands placed on the patient during the specific activity, for instance, if the patient displays weakness during stair climbing they should train by climbing stairs at different levels progressing to the actual level of their stairs and the number of stairs they commonly are faced with. The study by Mulrow et al[35] was the only FISCIT trial that used this principle in their intervention exercises but their results were modest due to excessive frailty of their subjects.

Physical Therapy Recommendations

Falls in the elderly are a result of multiple interrelated factors and thus require multidimensional team approach to intervention. Physical therapy plays an essential role in this team approach by strengthening weak muscles and providing adequate force production of the lower extremities and trunk for support of posture and control of balance.[3,50] However, to accurately treat elderly muscle weakness there first must be complete assessment of the patients individual deficits.[3,17,50]

Manual muscle testing is the most common method of muscle strength assessment,[81] yet in many cases manual muscle testing does not accurately assess the functional limitations caused by muscle weakness.[3] When attempting to prevent falls, it is essential to identify the elderly patients individual muscle function.[17] Careful observation, correct positioning and palpation are important for validity of testing. In addition, the clinician should determine the patient's level of motivation which can substantially influence the rating of strength. It is also important to include some functional tests (Appendix A), which often tend to provide more meaningful results than just simple manual muscle grading.[3]

No intervention will be effective without specifically addressing the faller's functional deficits.[14] Research shows that fallers display significant decrease in dynamic strength of the knees and ankles when compared to nonfallers.[11,15,17] The weakness is most prominent in the ankle dorsiflexion at high velocities of motion.[11] However, weakness in the hip musculature has also been significantly noted in elderly fallers.[15] In addition, research suggests that the loss of fast twitch (type II) muscle fibers in the elderly may increase their risk of falling due to the slowness of the muscles to respond to loss of balance.[17] It is critical to recognize these deficits so interventions can be focused on the appropriate strengthening and retraining of coordinated function.[11]

The use of the specificity of exercise principle and progressive resistance is recommended to ensure that the strengthening exercises employed in future fall intervention in fact strengthen the muscles that will functionally prevent falls and to ensure that the subjects strength will continue to improve with training.[17,82] There is a list of possible functional exercises provided in Appendix B. This list is by no means all-inclusive, but incorporates the use of progressive resistance and specificity of exercise principles and could act as a possible model for future fall interventions. Some of the exercises provided require less strength and would be beneficial for especially frail elderly but inappropriate for more functional elderly individuals. Exercises should be included, excluded and modified to the specific needs of each individual patient by a licensed physical therapist.

Before the implementation of any exercise program the patient should consult his or her physician. In addition, there are specific precautions that must be recognized when using strength training with an elderly population. The following is a list of four major guidelines that should be followed.[16]

1. Many elderly individuals have osteoporosis. Although resistance training has benefits in these individuals, unilateral weight bearing may be excessive for them. It is possible to fracture an osteoporotic bone during strengthening exercises so it is essential to progress slowly and think of safety first.

2. Many elderly individuals have osteoarthritis. Isometric exercises may be less painful for them. Prolonging the amount of time that the contraction is held is an effective way to increase strength without adding external resistance.

3. It is especially important for elderly individuals to avoid holding their breath (Valsalva's maneuver) during exercise. Counting outloud helps avoid this problem.

4. Elderly individuals should be taught to monitor their heart rate during exercise.

This independent study does not intend to suggest that strength training alone will prevent falls in the elderly population. Muscle weakness is merely one of many factors that cause falling. Physical therapy can effectively provide strengthening programs that will address the individual deficits found in elderly that are prone to falling, yet many other services may be needed. Physicians can provide the necessary changes in medications, nutritionists can provide the necessary changes in diet, and physical therapists and occupational therapists can provide gait and balance training, instruction in assistive walking devices, evaluation in home safety and can determine adaptive equipment that may be needed in the home.[50] The recommendations provided above are intended to be incorporated into an overall treatment plan that best meets the individual needs of the patient.

CHAPTER V

CONCLUSION

Falls among the elderly represent a major health problem with substantial medical and economical consequences. Falls are the leading cause of accidental death (and the seventh leading cause of death) in persons older than 65 years. In fact, of the elderly individuals that are hospitalized for a fall, only 50% live for one year thereafter.[63] To reduce the alarming rate of falls and related excessive mortality and morbidity, efforts to detect persons at risk and prevent or reduce the frequency of falls must be attempted. Facilitating such approaches requires a comprehensive understanding of the reasons elderly fall. Although research has identified many interacting factors that predispose individuals to falling, the approaches to fall prevention have not been well examined.[17]

Muscle weakness has been documented as a prominent risk factor for falls in the elderly population. This independent study reviews the causes of decreased muscle function in the elderly. Biologically, significant decreases in muscle mass, individual muscle fibers numbers, motor unit numbers and neural activation of motor units have been consistently seen in the elderly. Pathologically, many diseases and medications have shown to alter muscle function as people age. Functionally, inactivity and the fear of falling have also been shown to contribute to muscle weakness in the elderly.

Fortunately, muscle weakness that occurs with age can be reversed in many elderly individuals through the use of carefully implemented exercise programs. This literature review also details the improvements in muscle function using strength training in the elderly. Both healthy, community dwelling elderly and frail, institutionalized elderly were shown to obtain improved muscle function using isokinetic, isotonic and isometric strength training programs of varying duration.

In addition, the use of strength training in fall prevention programs was discussed in detail in this paper. In the few published studies available, strength training was shown to at least in part decrease the risk of falls in the elderly. The limitations of the research was discussed and physical therapy recommendations was presented.

Although the high prevalence and serious consequences of falls in the elderly are well known, research on fall prevention continues to be limited. Research is the only way effective prevention of falls can be achieved. Physical therapist are often in the ideal situation to implement the necessary fall prevention research. Without further effective research, the future elderly population may be at even further risk of falls.

APPENDIX A

FUNCTIONAL STRENGTH TESTING OF THE LOWER EXTREMITY

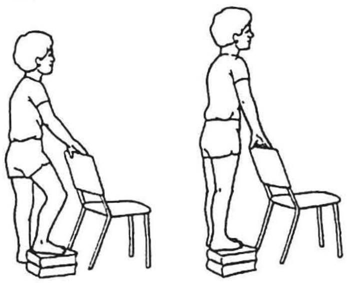
STARTING POSITION	ACTION	FUNCTIONAL TEST
Standing on one leg	Lift toes and forefoot off ground (dorsiflexion)	10-15 reps: functional 5-9 reps: functionally fair 1-4 reps: functionally poor 0 reps: nonfunctional
Standing on one leg	Lift heels of ground(plantar flexion)	10-15 reps: functional 5-9 reps: functionally fair 1-4 reps: functionally poor 0 reps: nonfunctional
Standing on one leg	Lift lateral aspect of foot off ground (ankle eversion)	5-6 reps: functional 3-4 reps: functionally fair 1-2 reps: functionally poor 0 reps: nonfunctional
Standing on one leg	Lift medial aspect of foot off ground (ankle inversion)	5-6 reps: functional 3-4 reps: functionally fair 1-2 reps: functionally poor 0 reps: nonfunctional
Sitting in chair with armrests	Stand (knee extension, hip extension)	Arises without use of hands: functional Arises using hands: functionally fair Arises with one or more attempts: functionally poor Requires assistance to stand: nonfunctional
Standing at the bottom of stairs	Ascend stairs (hip flexion, knee extension)	6-8 stairs with step over step ascent: functional 6-8 stairs with step to ascent: functionally fair 2-5 stairs with step to ascent : functionally poor Requires assistance to ascend stairs: nonfunctional

Appendix compiled from the following sources: 3,78,79

APPENDIX B

FUNCTIONAL LOWER EXTREMITY STRENGTH EXERCISES

1.



1. Place enough books on floor to total 2 inches tall
2. Hold onto solid object for support
3. Step up onto books with right foot
4. Slowly lower
5. Repeat on opposite foot
6. Progress by increasing the height of the books until equal to height of your stairs
7. Can also use a step to progress, or slowly add ankle weights

GOAL To increase quadriceps strength in stair climbing activities

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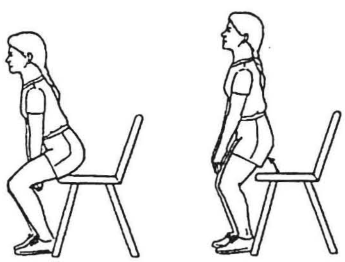
2.



1. Sit on edge of chair, feet flat on floor
2. Stand upright
3. Initially use arm rests for support and progress to standing without using arm rests for support

GOAL To increase quadriceps and hip extension strength for sit to stand activities

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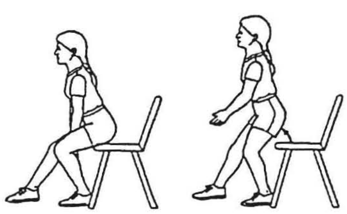
3.



1. Advanced version of exercise #2
2. Sit on edge of chair as shown, with right foot closest to chair
3. Stand upright, letting the left leg help as little as possible
4. Repeat with the left foot close to the chair letting the right leg help as little as possible

** GOAL** To increase quadriceps and hip extension strength for sit to stand activities.

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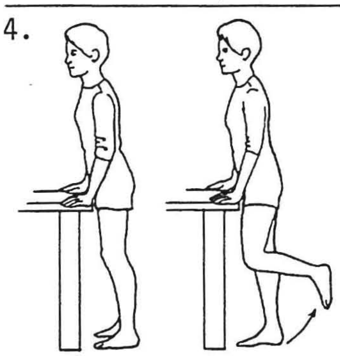
4.



1. Stand holding onto a solid object as shown
2. Slowly bend the right knee
3. Hold 5 seconds and slowly lower
4. Repeat using left knee

GOAL To increase hamstring strength in gait activities

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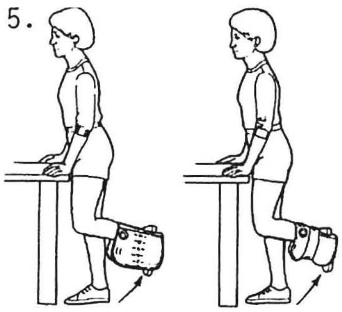
5.



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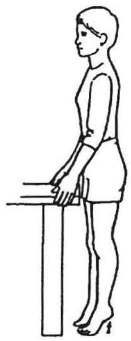
1. Advanced version of exercise #4
2. Follow directions in exercise #4
3. Progress by gradually increasing ankle weight
4. May also perform using theraband

GOAL To increase hamstring strength for gait activities

6.



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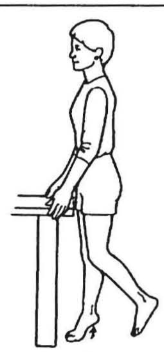
1. Stand with feet 12 inches apart
2. Raise up slowly onto your toes as high as you can
3. Hold 5 seconds and relax

GOAL To increase ankle strength for stair climbing and gait

7.



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1, Advanced version of exercise #6
2. Stand on one foot while holding on to sturdy object
3. Raise up slowly onto your toes as high as you can
4. Hold 5 seconds
5. Repeat on opposite foot

GOAL To increase ankle strength for stair climbing and gait

8.

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1. Sit in a chair with knees bent as shown
2. bend right hip to lift foot off floor
3. Hold 5 seconds, slowly relax
4. Repeat with left hip

GOAL To increase quadriceps strength for stair climbing and gait

9.

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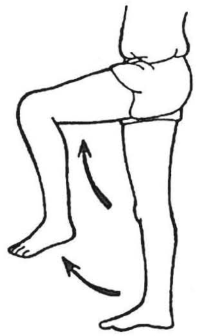
1. Advanced version of exercise #8
2. Follow directions in exercise #8
3. Progress by slowly increasing ankle weight

GOAL To increase quadriceps strength for stair climbing and gait

10.



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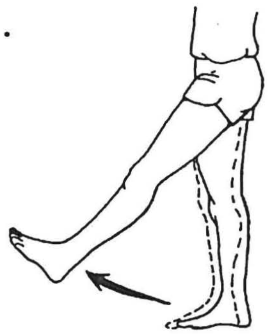
1. Advanced version of exercise #9
2. Stand with legs straight, using sturdy object for support
3. Bend right knee and hip upward as shown
4. Hold 5 seconds, slowly relax
5. Repeat on left leg
6. May progress this exercise by adding ankle weight or using theraband

GOAL To increase quadriceps strength for stair climbing and gait

11.



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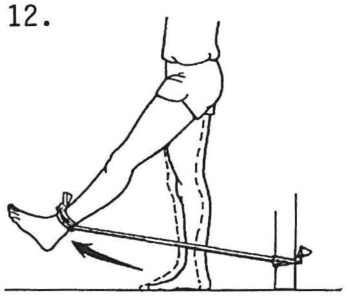
1. Stand with legs straight, using sturdy object for support
2. Lift leg forward, keeping knee straight as shown
3. Hold 5 seconds, slowly relax
4. Repeat on left leg

GOAL To increase quadriceps strength for gait

12.



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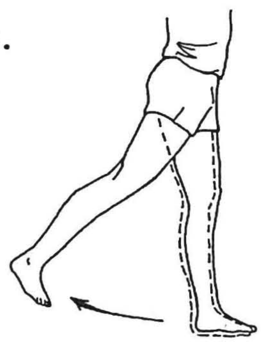
1. Advanced version of exercise #11
2. Follow directions of exercise #11
3. Progress using theraband

GOAL To increase quadriceps strength for gait

13.



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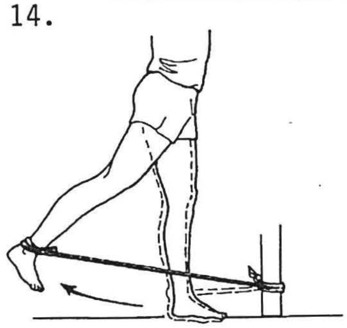
1. Stand with feet slightly apart, using sturdy object for support
2. Lift right leg backwards as shown
3. Hold 5 seconds, slowly relax
4. Repeat on left leg

GOAL To increase hip extensors strength for gait activities

14.



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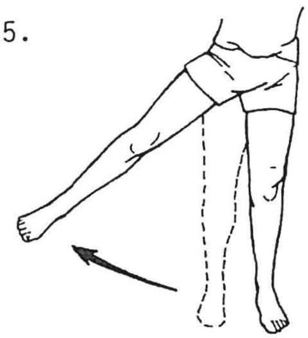
1. Advanced version of exercise #13
2. Follow directions of exercise #13
3. Progress using theraband

GOAL to increase hip extensor strength for gait activities

15.



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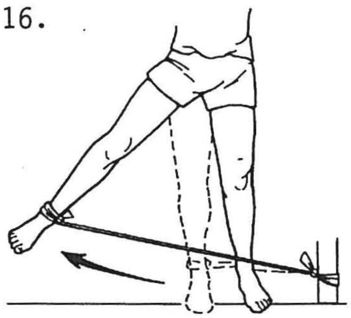
1. Stand holding onto solid object for balance
2. Raise right hip out to side, without letting it come forward
3. Hold 5 seconds, slowly relax
4. Repeat on left leg

GOAL to increase hip abduction strength for gait activities

16.



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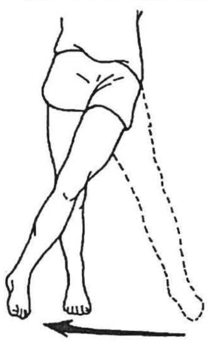
1. Advanced version of exercise #15
2. Follow directions of exercise #15
3. Progress using theraband

GOAL To increase abduction strength for gait activities

17.



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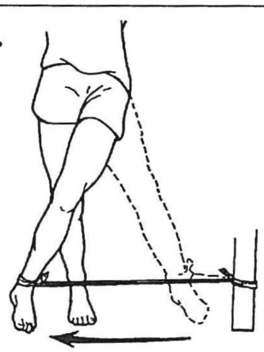
1. Stand with right toe pointing out to side as shown, using solid object for support
2. Now cross the leg in front of your other leg
3. Hold 5 seconds, slowly relax
4. Repeat on left leg

GOAL To increase hip adduction strength for gait activities

18.



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1. Advanced version of exercise #17
2. Follow directions in exercise #17
3. Progress using theraband

GOAL To increase hip adduction strength for gait activities

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