Exercise Effects on Falls in Frail Elderly: Focus on Strength

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Given that lack of exercise independently predicts mobility decline (Graafmans et al., 1996), and that mobility decline is associated with increased risk for falls, it is no surprise that there is great interest in promoting exercise among the burgeoning group of older adults in this country. Not only is the population of those over 65 years of age expected to increase dramatically in the next decade, but those over 85 years of age are the faster growing segment of aging America. In the next 15 years, the number of adults over the age of 85 years is expected to double (Suzman, 1992).

The incidence of frailty, defined by Buchner (Buchner & Wagner, 1992) as "a loss of physiologic reserve that leads to decline in physical performance and functional independence," is increasing with the graying of America. It is estimated that for every one resident of a nursing facility, there are at least two community-dwelling individuals who are equally functionally impaired (Suzman, 1992). Thus, interventions to promote physical function may be key to preventing long-term placement in nursing facilities. The frail group of elderly, typically over 70 years of age, includes both the physically frail, those who can perform only basic activities of daily living (food preparation, grocery shopping, light housekeeping) and may be homebound, and the physically dependent, those who cannot perform some or all basic activities of daily living and need home or institutional care (Spiriduso, 1995). Falls are more common in frail individuals.

There is considerable evidence that reduced muscle strength and power are the primary causes of decreased function in the older adult. Further, these declines continue into older age and are associated with increased risk for falls. Approximately 30% of individuals over the age of 60 years fall each year, and this value increases to 50% in adults over the age of 75 years. Falls pose a major threat to older adults given their central role in both hip and vertebral fractures. Annually in the U.S., 90% of the 300,000 hip fractures result from a fall, whereas falls account for approximately 50% of the reported 500,000 vertebral fractures (Cummings, Kelsey, Nevitt, & O'Dowd, 1985; Myers, & Wilson, 1997; Norton, Campbell, Lee-Joe, Robinson, & Butler, 1997). In the U.S., hip fractures carry a staggering economic burden of $14 billion annually (Ray,

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Chan, Thamer, & Melton, 1997). Furthermore, falls that result in serious injury independently predict placement in nursing homes (Tinetti & Williams, 1997).

**Risk Factors for Falls**

Risks for falls include both intrinsic and extrinsic factors. Of the intrinsic factors, *fear of falling* and *neuromuscular performance variables* are likely those most modifiable by exercise intervention. Fear of falling has been reported to cause reduced activity in 20% of over 1,000 adults over 72 years (Tinetti, Mendes de Leon, Doucette, & Baker, 1994). Among nursing home patients, fear of falling has been reported to be a clinically important predictor of functional decline (Franzoni, Rozzini, Boiffieri, Frisoni, & Trabucchi, 1994). In this study, fear of falling was predictive of a decline in activities of daily living (ADL’s) after controlling for cognitive function, age, gender, balance, gait, frequency of medications, and co-morbidity. In a large cohort of elderly subjects, Tinetti and colleagues (1994) reported a strong independent association between self-efficacy and function. Thus, exercise programs that promote physical function should also increase confidence and reduce fear of falling.

The neuromuscular performance variables include lower extremity strength and power, biomechanical measures of balance, dynamic posturography, and clinical measures of physical function, also known as functional or mobility measures (i.e., gait, chair raise, sit to stand). These measures are associated with falls in one or more studies (Dargent-Molina et al., 1996; Fleming, Wilson, & Pendergast, 1991; Maki, Holliday, & Topper, 1994; Thapa, Gideon, Brockman, Fought, & Ray, 1996; Whipple, Wolfson, & Amerman, 1987). However, it is atypical that each is assessed either in cross-sectional or intervention studies. Gait changes (i.e., speed and stride width) and other clinical measures of function as well as ankle dorsiflexion have been shown to predict falls or indicate fear of falling (Maki, Holliday, & Topper, 1991; Maki, 1997; Thapa et al., 1996; Tinetti & Williams, 1997). Specifically, reduced ankle dorsiflexion, quadriceps strength, leg power, gait speed, and increased stride width increase the likelihood of falls (Maki, 1997). Lower extremity strength and power can be measured as a composite of ankle, knee, and hip activity using instruments such as the Nottingham power rig (Basley & Short, 1990) or using isometric, isotonic, or isokinetic devices to assess ankle, knee, and hip strength separately. Since there is such a variety of measurement instruments (isometric, isokinetic, isotonic) and tests within the postural stability (static, eyes open and closed, dynamic with and without perturbation) and the clinical measures category (functional reach, sit to stand, chair rise, tandem gait speed, forward and backward, tandem gait), it remains unclear as to which tests consistently predict falls and which are appropriate for a frail population. More importantly, few studies have carefully identified the tests most predictive of injurious falls (Dargent-Molina, 1996; Lord, Sambrook et al., 1994; Nevitt, Cummings, & Hudes, 1991). As stated before, the specific changes in gait and other muscle groups that may be important for injurious falls warrant comprehensive examination.

Since many exercise intervention studies evaluate fall risk variables and not falls as outcomes, it has been important to evaluate the predictive capability of specific measures of strength that predict postural sway. For example, in many studies, functional tests of mobility that accommodate clinical and residential settings are used as surrogates for laboratory measures of strength, power, and postural stability. Specifically, there has been a question as to whether or not biomechanical measures of postural sway correlate with both laboratory tests of lower extremity of muscle strength and power and clinical tests of mobility. Although these relationships have not been widely examined, a limited
number of studies report that biomechanical measures of postural sway show modest to
good correlations ($r$ from 0.35 to 0.65) with mobility in frail elderly (Berg, Maki,
Williams, Holliday, & Wood-Dauphinee, 1992; Thapa et al., 1996).

With regard to the relationship between mobility and laboratory measures of
muscle strength and power, reports generally support a positive correlation between clini-
cal measures of mobility and laboratory measures of strength and power (Bassey &
Short, 1990; Shumway-Cook, Gruber, Baldwin, & Liao, 1997). The few reports of cor-
correlations between laboratory measures of strength and power and balance demonstrate
that strength measures are predictive of biomechanical measures of postural stability
(Shaw & Snow, unpublished data; Wolfson, Judge, Whipple, & King, 1995). At the Bone
Research Laboratory, we have observed that, in healthy older women (average age = 63
years), ankle dorsiflexion and hip abductor strength are independent predictors of both
static and dynamic balance assessed by dynamic posturography. Ankle dorsiflexor
strength was specific to balance in the posterior direction, while hip abductor strength
best predicted dynamic balance in the medial lateral direction. These data lend support
to the notion of strengthening these muscle groups to reduce backward and side falls,
both highly associated with fractures. Whether these correlations hold for a frail popu-
lation or whether they predict injurious falls is not known.

**Strength Training Interventions**

Since lower extremity strength is central to balance, gait and occurrence of falls (Graaf-
mans, 1996; Wolfson et al., 1995), it is not surprising that exercise interventions
designed to promote strength among the elderly are the focus of increasing research, par-
icularly among those elderly living in the community. As previously mentioned, for
every one nursing home resident, there are at least two community-dwelling individuals
who are equally functionally impaired.

Do exercise interventions that focus on resistance training reduce falls and fall
risk? Exercise interventions are relative newcomers to the field of falls and fall risk, and
studies are mixed both with respect to exercise design and outcome variables. Many
studies lack control groups, are not randomized, lack progression and adequate intensity,
and have primarily used seated protocols (machine weights) that do little to challenge
the neuromuscular mechanisms that underlie postural control. The primary outcome
measures include both neuromuscular predictors of fall risk and assessment of falls. The
neuromuscular measures vary widely across interventions and also carry very different
precision errors, not always reported in the literature.

**Effect on Fall Risk**

The few strength training interventions for frail adults have resulted in improvements in
neuromuscular variables that predict falls from using low-to-moderate (Chandler,
Duncan, Kochersberger, & Studentski, 1998; Sauvage et al., 1992; Wolfson, Whipple et
al., 1996) and high intensity (Fiatarone, Marks, et al., 1990; Fiatarone, O’Neill et al.,
1994) resistance training. In a landmark study, Fiatarone, Marks et al. (1990) reported
enormous strength gains (up to 174%) as well as improvements in tandem gait speed in
frail residents of a nursing facility (>90 years) after 8 weeks of high intensity (85%
1RM), machine-based strength training. Although the group was small ($n = 10$) and
lacked a control, this was the first attempt to transcend the mindset that elderly individ-
uals should not and cannot be challenged at intensities similar to those of younger adults
and that exercise could not influence fall risk.
Since that time, there have been more and varied reports of the effects of muscle building exercise on fall risk. Fiatarone, O’Neill, and colleagues (1994), a FICSIT (Frailty and Injuries: Cooperative Studies of Intervention Techniques) site reported that 10 weeks of high intensity resistance exercise in frail elderly, increased muscle strength by 113%, stair climbing power and gait velocity by 28% and 11%, respectively, and thigh muscle cross-sectional area by 2.7%. Using lower intensity strength training, Wolfson, Whipple et al. (1996), also a FICSIT site, observed strength gains in frail subjects and found no interaction between balance and strength training. In a randomized weight training study, Chandler et al. (1998) reported significant gains in lower extremity strength in a large group of frail adults (M = 78 years) who participated in 10 weeks of at-home exercise. Strength gain was associated with increases in chair rise performance, gait speed, and mobility tasks such as stair climbing, but not with improved endurance, balance, or disability. An important finding was that confidence in mobility improved with increased strength, indicating that these individuals may become more active in their daily lives, an outcome associated with increased function. At first glance, it may be surprising that increases in lower extremity strength are not necessarily associated with improvements in balance. However, it is important to recognize that most strength training regimens have been performed in the seated position requiring less postural adaptation than would standing exercise.

Among those studies that evaluate fall risk, a few studies have used multidimensional programs designed by physical therapists, which include some strength training in the varied program and are individualized for each subject. Others strictly emphasize weight training and apply a generalized program to all participants. While, in most cases, the programs improved balance and mobility, given the varied nature of these protocols, it is difficult to ascertain a dose response and impossible to generalize results. Also, one study actually resulted in an increased fall incidence (Mulrow et al., 1994).

**Effect on Falls**

The FICSIT trials involved seven sites and had multiple aims, one of which was to evaluate if short-term exercise reduced falls and fall-related injuries in elderly (>70 years) individuals who were frail but had no severe cognitive impairment or illness. In a pre-planned meta-analysis, general exercise including progressive strength training and endurance activities had a falls incidence ratio of 0.90, but was not as effective as "balance" exercises with a ratio of 0.83. However, no exercise component was significant for injurious falls, but according to the authors, power was not high enough to detect an effect.

Although aimed at fall reduction, Lord, et al. (1995) reported that a 12-month multidimensional program that improved strength and balance resulted in no difference in falls between exercise and control groups, but adherence to the exercise was associated with fewer falls. Those individuals reporting attending more than 75% of the exercise classes had fewer falls compared to those attending fewer than 75% and controls. It is not clear from the discussion whether or not the higher attendance was associated with greater gains in strength and (or) balance.

A very recent report from New Zealand has shown that strength training does reduce both falls and injurious falls in frail elderly individuals (Campbell et al., 1997). In a randomized exercise intervention using a mixed program of muscle building and walking, Campbell and colleagues (1997) showed a reduction of over 40% in non-injurious and injurious falls. While encouraging, it is not evident whether the reduction in
falls resulted from the individualized low intensity muscle building exercise, from increased walking activity, or from a combination of regimens.

Effect on Injurious Falls

While the above-cited studies provide support for strength training as a method for reducing falls and some but not all factors associated with fall risk, programs have not been tailored to target falls associated with hip fractures. Hip fractures, the most devastating of all injuries, occur in 1–5% of falls and account for most of the economic costs associated with falls. After a hip fracture, 50% of individuals no longer function independently. By age 90, one third of all women and one sixth of all men will fracture a hip. Long considered a disease of low bone mass, it is now clear that the primary cause of a hip fracture is a fall (Cummings, Kelsey, Nevitt, & O’Dowd, 1985; Dargent-Molina et al., 1996; Norton et al., 1997). As mentioned earlier, 90% of hip fractures result from a fall, and a fall to the side directly on the hip increases the risk of hip fracture six fold (Hayes et al., 1992).

To address factors that may modify risk factors for hip fractures (in particular, medial-lateral balance, given its expected association with side falls), we conducted two studies to examine effects of resistance training on hip fracture risk in healthy older (M = 55–70 years) and frail osteoporotic women (85–93 years) (Protiva, Macdonald, Winters, & Snow, 1997; Shaw & Snow, 1998). Both investigations evaluated the effects of the same, but modified, progressive strength training program using weighted vests as resistance on tperformance variables related to falling and on bone density (BMD). The exercise program included exercises that mimicked daily activities (e.g., chair raises, stepping) and those that were different from daily activities (e.g., lunges to the side and back, squatting without sitting).

In the younger elderly population, after 9 months of training, strength and power increased in the exercise group but not in the control group with the greatest increases in hip abductor and ankle plantar flexion. There was a 35% improvement in medial-lateral dynamic balance, but no change in anterior-posterior balance. In correlation analysis, the increase in hip abductor strength was significantly associated with the improvement in medial-lateral dynamic balance. This suggests that specific training of the hip abductors improved lateral stability. Whether this association would be observed from machine-based seated exercise is not known, but we speculate that the postural adjustments required for activities performed in the standing position are superior to seated, machine-based strength training. Although there was no significant gain in hip BMD, we did observe later in the program an increase in femoral neck BMD to 2% after 1 year of jumping with weighted vests (Winters, Shaw, Voegeli, & Snow, 1998).

In the frail population, training was adapted from that used with the higher functioning, younger elderly. These modifications included: 3 months of training without weights in the vests, more time to learn correct form of exercises, lower intensity and volume, slower progressions, and more assistance (one staff member for every two subjects during stepping and lunging activity). Measures included clinical as well as laboratory tests. After 6 months of weighted vest exercise, we observed significant improvements of 30–40% on four measures of gait, one of which included a medial-lateral component (the circular path) (Protiva et al., 1997). No significant changes were apparent at 3 months, which was not surprising given that the vests were not weighted until the end of the 3rd month. Further, bone mass did not change at the hip. We also evaluated 6 months of detraining and found that performance on the gait tests declined to pre-
training levels. Unlike our younger, healthy older adults, no changes were seen in the laboratory measures of isokinetic strength (KinCom) or dynamic posturography (Neurocom).

The lack of change in dynamic balance is somewhat puzzling given the dramatic improvements in gait and power. We believe that in this frail population, the equipment was intimidating (i.e., computerization, harnessing, unfamiliarity), and thus, did not provide results consistent with the clinical measures. Lastly, in this frail group of women, we have anecdotal evidence of the relationship between improved function and confidence. Although we did not measure fall efficacy, the participants had more confidence in their physical abilities (i.e., chose stairs more often) after 6 months of exercise and were less fearful of falling. Furthermore, at the end of the study, each woman was able to rise from a chair without using her hands, a task that no one could execute prior to the study.

**Summary**

The goals of an exercise program to reduce falls and fall risk for individuals with minimal cognitive and neurological impairment should be to improve physical function (lower extremity strength and balance) and reduce fear of falling. The program should be safe, practical, inexpensive, easily adapted at-home or in groups, promote independence, and generalize to a wide population of community and institutionalized older adults. This approach would reduce the need for high-cost physical therapy on an individual basis. Further research is needed to identify predictors of injurious falls, specifically those causing hip fractures, in order for exercise training programs to serve as sites of preventive care.

**References**


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