2008

Does balance training improve balance in physically active older adults?

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Does balance training improve balance in physically active older adults?

by

Kristen Kartchner Maughan

A thesis submitted to the graduate faculty
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Major: Kinesiology (Biological Basis of Physical Activity)

Program of Study Committee:
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Ames, Iowa
2008

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For my Dad

who taught me that age is never a reason to stop learning or playing handball.
# TABLE OF CONTENTS

**LIST OF FIGURES** vi

**LIST OF TABLES** vii

**ABSTRACT** viii

**CHAPTER 1. INTRODUCTION** 1

**CHAPTER 2. REVIEW OF LITERATURE** 5

- Measures of Balance and Mobility
  - Balance 5
  - Mobility 9

- The Effect of Physical Activity on Balance Regulation
  - Overview 11
  - General Physical Activity 14
  - Multi-modal Physical Activity Programs 15
  - Resistance Training 17
  - Balance Activities 20

- Overall Summary and Proposed Research 24

**CHAPTER 3. METHODS** 27

- Participants 27
- Intervention 28
- Outcome Measures 30
  - Clinical Measures 31
  - Posturographic Measurements 31
  - Gait Analysis 34

- Statistical Analysis 34

**CHAPTER 4. RESULTS** 35

- Clinical Measures 35
- Posturography 38
- Gait Analysis 42

**CHAPTER 5. DISCUSSION** 43

- Conclusion 56

**REFERENCES** 58

**APPENDIX A: BALANCE-TRAINING PROGRAM** 65

- Session 1 65
- Session 2 66
- Session 3 67
- Session 4 68
LIST OF FIGURES

Figure 1. Potential Impact of Physical Activity on the Risk for Falls and Fractures 12
Figure 2. Percent Change for Single-leg-stance Times 35
Figure 3. Percent Change for Alternate Stepping Time 36
Figure 4. Percent Change for Limits-of-stability 95% Area Ellipse 38
Figure 5. Percent Change for Limits-of-stability AP Maximum Excursion 39
Figure 6. Percent Change for Foam-eyes-open/Foam-eyes-closed ML Sway Velocity Difference Scores 40
LIST OF TABLES

Table 1. Commonly Used Measures of Balance and Mobility 6
Table 2. Baseline Characteristics 28
Table 3. Summary of Clinical and Gait Results by Intervention Group 37
Table 4. Summary of Posturographic Results by Intervention Group 41
ABSTRACT

Falls among older adults are a growing public health problem. Previous research suggests that the regular practice of physical activity in older adults improves balance and reduces falls. The objective of this study was to determine whether balance-specific training, in addition to regular physical activity, could improve balance in older adults, and whether there would be a dose-response to frequency of balance training.

A six-week balance-training program was conducted with 60 older adults (60-87 years) who were already participating in a regular program of physical activity. All participants continued with their regular exercise program while adding balance training in one of three doses: three 20-minute balance-training sessions/week (3-Day); one 20-minute balance-training session/week (1-Day); and no additional balance training (Control).

Participants were tested pre-and post-training and a repeated measures ANOVA revealed significant intervention effects of training for 1) single-leg-stance on the left (p=.019) and right (p=.026), 2) limits-of-stability 95% area ellipse (p=.036) and anteroposterior maximum excursion (p=.01), 3) foam eyes closed/foam eyes open mediolateral difference score (p=.008), and 4) a trend toward significance for alternate stepping (p=.053). Both 3-Day and 1-Day groups saw more improvement than controls, with the 3-Day group achieving the greatest improvements overall. The results of this study suggest that physically active older adults who exercise regularly can benefit from the addition of balance training to their current exercise program. Three 20-minute sessions per week led to the greatest improvement; however it appears that even one 20-minute session of balance training per week may lead to improvement of balance.
CHAPTER 1. INTRODUCTION

The American population is getting older. In the year 2003, there were 35.9 million Americans over the age of 65, representing 12.4% of the population. By the year 2030, the older adult population is expected to more than double in size, accounting for 20% of the population (Greenberg, 2004).

Falls among older adults are a growing public health problem. According to the Centers for Disease Control and Prevention, more than one third of Americans over the age of 65 fall each year (Centers for Disease Control and Prevention, 2006). Among those who fall, 20-30% sustain moderate to severe injuries that lead to a reduction in mobility and independence (Sterling, O’Connor & Bonadies, 2001). Repeated falls and instability are a common reason for nursing home admissions (Rubenstein, 2006) and those over the age of 75 who fall are four to five times more likely to be admitted to a long-term care facility (Donald & Bulpitt, 1999). Falls are the leading cause of injury deaths in older Americans and only about half of those admitted to a hospital after a fall will still be living one year later (Centers for Disease Control and Prevention, 2006).

The cause of falls in older adults is multifactorial. Falls often stem from the interaction between intrinsic and extrinsic factors—between individual susceptibility and environmental hazards. Intrinsic factors include lower extremity weakness, balance and gait disorders, visual impairment, cognitive impairment and other medical conditions, while extrinsic factors include polypharmacy (the use of 4 or more medications) and environmental hazards such as loose carpets, cluttered walking paths, poor lighting, and lack of safety equipment such as handrails in bathrooms (AGS Panel on Falls Prevention, 2001). Successful
mobility and balance control are dependent upon the skill and capability of the individual, the difficulty of the task or activity, and the extent of the environmental challenges (Frank & Patla, 2003). The most important identifiable individual risk factors in the etiology of falls are muscle weakness and balance and gait problems (Rubenstein, 2006).

Older adults who have fallen, as well as those who have not, may experience a fear of falling leading to activity restriction (Tinetti, Medes de Leon, Doucette & Baker, 1994). In particular, those with a previous history of an injurious fall are much more likely to restrict activities (Murphy, Williams & Gill, 2002). Restriction of activity secondary to fear of falling is associated with a decline in physical performance measures, including reduction in mobility and balance. Thus, fear of falling, even in the absence of having done so, may predispose older adults to other functional limitations. Both activity avoidance and a fear of falling may be contributors in the transition to physical frailty (Delbaere, Crombez, Vanderstraeten, Willems & Cambier, 2004).

Preserving balance and mobility is essential to successful aging. Good balance is necessary to perform activities of daily living such as rising from a chair or transcending a flight of stairs. It is fundamental to a physically active lifestyle and crucial in sustaining independence in the elderly. Fortunately, many risk factors for falls can be improved through treatment, meaning that falls may potentially be preventable or at least reduced.

Substantial evidence suggests that the regular practice of physical activity in older adults will have a positive impact on balance, mobility, and the reduction of falls. In 2007, the American College of Sports Medicine (ACSM) and the American Heart Association (AHA) issued a joint statement on physical activity and public health in older adults (Nelson et al., 2007). Along with specific recommendations for older adults to engage in regular
aerobic activity and strength training, this paper included a recommendation for community-
dwelling older adults with substantial risk of falls to engage in balance training. There are
specific guidelines for dose and frequency for both aerobic and strength training activities;
however, there are no recommendations as to the frequency or duration of balance training.

This study addresses two questions emerging from these guidelines. First, is balance
training beneficial for older adults who already participate in a regular program of physical
activity? Since the majority of intervention studies have been conducted on sedentary or frail
older adults, the addition of exercise, regardless of mode, seems to lead to balance
improvement. There is little evidence to suggest that those who are already meeting current
physical activity guidelines would derive additional benefits from balance training.
Nevertheless, is it prudent to wait to encourage balance training in older adults until they are
at substantial risk of falls as suggested in the ACSM and AHA guidelines? Second, how
much and how often should active older adults participate in balance training to obtain a
beneficial effect? To date, no studies have compared the effect of frequency of balance-
specific training on measures of dynamic and static balance, and there are no established
guidelines to address this question.

Based on these questions and the published research, we hypothesized that in a
population of physically active older adults, there would be an improvement in balance and
gait measures after a six-week balance training program. We also hypothesized that there
would be a dose-response relationship between the frequency of balance training and the
level of improvement in balance control.

In order to test these hypotheses, a six-week balance-training program was conducted
with active adults aged 60 and older. To be included in the study, participants had to be
currently participating in a regular program of physical activity, consisting of a minimum of
30 minutes of aerobic activity three days per week and including strength training two or
more days of the week. Sixty-one older adults were included in the study and randomized
into three age-matched groups: a 3-day per week training group, a 1-day per week training
group, and a control group. Participants were tested pre-and post-training using both clinical
and laboratory measures of balance and gait, and a balance confidence scale. A repeated
measures analysis of variance (ANOVA) revealed significant intervention effects for single-
leg-stance, and two posturographic measures on the balance platform (limits-of-stability and
foam eyes closed/foam eyes open difference score). A trend toward significance was seen for
alternate stepping. No significant effects were seen in gait measures. These results suggest
that in physically active older adults, the addition of balance training to regular physical
activity may lead to an improvement in balance, but not gait control, with three 20-minute
sessions of balance training per week leading to the greatest benefits.
CHAPTER 2. REVIEW OF LITERATURE

Measures of Balance and Mobility

A number of clinical and laboratory tools have been developed to measure balance and mobility, and an understanding of these measures is necessary before undertaking a review of the literature on the subject of balance. A brief description of some of the most common balance assessment tools used can be found in Table 1. One of the difficulties in interpreting the literature is the lack of a “gold standard” in the measurement of balance. The type of test, parameters measured, procedures used, and results vary widely from study to study. In addition, there are vast differences in age and physical capacity of study populations, ranging from the young-old (60-70 years) to the old-old (80+ years), and from the frail elderly, including nursing home residents, to physically active, independent older adults. Thus it is difficult to compare one study to another, and a ceiling effect may be an important issue to consider in populations with high physical functioning.

Balance

A gradual decline in balance performance and mobility occurs with age as measured by clinical methods (Bohannon, Larkin, Cook, Gear, & Singer, 1984; Isles, et al., 2004; Steffen, Hacker & Mollinger, 2002) as well as posturographic methods (Baloh et al., 1994; Camicioli, Panzer, & Kaye, 1997; Cohen, Heaton, Congdon & Jenkins, 1996; Low Choy, Brauer & Nitz, 2003). Deviations from age-related decline may be used to assess balance impairments and risk of falling.

Numerous studies have investigated the relationship of clinical measures to the incidence of falls in older adults. Vellas et al. (1997) found the inability to maintain single-
### Table 1. Commonly Used Measures of Balance and Mobility

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Measure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Narrow stance</td>
<td>Static balance</td>
<td>Timed stand with feet together (eyes open or closed)</td>
</tr>
<tr>
<td>Functional Reach</td>
<td>Dynamic balance</td>
<td>Standing forward reach</td>
</tr>
<tr>
<td>360 Turn</td>
<td>Dynamic balance</td>
<td>Timed 360 degree turn</td>
</tr>
<tr>
<td>Single-leg-stance (SLS)</td>
<td>Static balance</td>
<td>Timed stand on one leg (eyes open or closed)</td>
</tr>
<tr>
<td>Tandem Stance Time</td>
<td>Static balance</td>
<td>Timed stance with a narrow base of support—feet placed heel-to-toe (eyes open or closed)</td>
</tr>
<tr>
<td>Timed Up &amp; Go (TUG)</td>
<td>Dynamic balance, lower body strength, mobility</td>
<td>Timed rise from a chair, walk a predetermined distance, turn, return to chair and sit down.</td>
</tr>
<tr>
<td>Walk test</td>
<td>Dynamic balance and mobility</td>
<td>Measured <em>distance</em> walked in a certain period of time, OR Amount of <em>time</em> taken to walk a certain distance.</td>
</tr>
<tr>
<td>Sit-to-Stand</td>
<td>Dynamic balance, lower body strength</td>
<td><em>Number</em> of times one can rise from a chair (arms crossed over chest) in a given period of time, OR <em>Time</em> it takes to rise from a chair a predetermined number of times</td>
</tr>
<tr>
<td>Tinetti Performance Oriented Mobility Assessment (POMA)</td>
<td>Static &amp; dynamic balance, gait</td>
<td>Scored based on performance of 2 batteries of tests; one to measure balance (standing &amp; sitting balance, 360° turn, response to perturbation), and one to measure gait.</td>
</tr>
<tr>
<td>Berg Balance Scale</td>
<td>Static &amp; dynamic balance</td>
<td>Scored based on performance of a battery of tests measuring standing and sitting balance, weight transfers and movement. Includes functional reach, narrow and tandem stance, SLS, and 360 degree turn.</td>
</tr>
<tr>
<td>Computerized Posturography (including limits-of-stability)</td>
<td>Static &amp; dynamic balance</td>
<td>Measurement of foot center of pressure area, sway, and velocity of sway in both anteroposterior and mediolateral directions while standing on a force platform. Platform can be fixed or moving.</td>
</tr>
<tr>
<td>Sensory Organization Test (SOT)</td>
<td>Static &amp; dynamic balance</td>
<td>Measures 6 conditions of increasing difficulty and sensory conflict on a force platform—stance with eyes open, eyes closed, and moving visual field are measured on both a fixed support surface and a moving surface.</td>
</tr>
<tr>
<td>Gait Analysis</td>
<td>Gait characteristics, mobility</td>
<td>Measurement of stride cycle, length, width, velocity, cadence (number of steps/unit of time), and time in double and single leg support.</td>
</tr>
</tbody>
</table>
leg-stance (SLS) for 5 seconds or more to be the strongest predictor of injurious falls in community-living older adults. In contrast, Buatois, Gueguen, Gauchard, Benetos, and Perrin (2006) found that SLS (timed for 5 seconds), the Timed Up & Go and sit-to-stand tests were not predictive of falls in non-institutionalized elders. The disparity between study results may be in part because Vellas et al. (1997) measured _injurious_ falls, while Buatois et al. (2006) looked at all falls. A longer measure of SLS time may be more discriminatory in an active older population. Hurvitz, Richardson, Werner, Rhul, and Dixon (2000) compared community-dwelling fallers and non-fallers aged 50 and older and found SLS times of less than 30 seconds to be associated with a history of falling, while SLS times of greater than or equal to 30 seconds were associated with a low risk of falling. Stel, Smit, Pluijm and Lips (2003) found that the inability to perform tandem stance for 10 seconds or more was almost as strong a predictor of recurrent falls as more sophisticated posturography tests.

While single measures of static or dynamic balance may have some predictive value of future falls, there may be more validity in using a series of clinical measures scored together. Clinical scales such as the Tinetti Performance Oriented Mobility Assessment (POMA) and the Berg Balance Scale have been shown to have value in assessing balance and future risk of falls (Berg, Maki, Williams, Holliday & Wood-Dauphinee, 1992; Lajoie & Gallagher, 2003; Thapa, Gideon, Brockman, Fought & Ray, 1996). A validation study of the Frailty and Injuries: Cooperative Studies of Intervention Techniques found moderate correlations between physical functioning and static balance when using a battery of tests including narrow, semi-tandem, tandem and single-leg stances (Rossiter-Fornoff, Wolf, Wolfson, & Buchner, 1995). A recently developed tool, the Fullerton Advanced Balance scale, may be useful in the assessment of functionally independent older adults. This tool
uses more challenging balance conditions and longer hold times in comparison to the other balance scales. Rose, Lucchese, & Wiersma (2006) tested the validity and reliability of this scale with preliminary results suggesting it is a more sensitive measure for physically active older adults who may experience a ceiling effect with the Tinetti POMA or the Berg Balance Scale. Because of its recent development, however, few studies have implemented the Fullerton Advanced Balance Scale.

Laboratory measures of computerized posturography using a force platform may provide better sensitivity than clinical testing for assessment of balance, although controversy exists as to whether these measures are related to falls (Baloh et al., 1994; Boulgarides, McGinty, Willett, & Barnes, 2003; Piirtola & Era, 2006). A variety of parameters can be measured with posturography, but indicators of sway in the mediolateral plane appear to be the most consistently correlated to future risk of falls (Brauer, Burns, & Galley, 2000; Lajoie and Gallagher, 2003; Maki, Holliday, & Topper, 1994; Melzer, Benjuya, & Kaplanski, 2004; Piirtola & Era, 2006; Thapa et al., 1996; Topper, Maki, & Holliday, 1993; Stel, et al., 2003).

Posturography may be especially important in populations of older adults with high functional capacity. Using the measure of mediolateral sway in narrow base stance, Melzer et al. (2004) were able to distinguish fallers (at least 2 falls in the past 6 months, n=19) from non-fallers (n=124) in a population of independent, community-dwelling older adults. In contrast, Boulgarides et al. (2003) were unable to predict future falls over a period of 12 months in a population of 99 active older adults using posturography. Buatois et al. (2006) studied 206 healthy, non-institutionalized adults and also found no significant differences between fallers and non-fallers on clinical tests of balance or simple static and dynamic posturography. However, by using the Sensory Organization Test (SOT), which involves
sensory conflict (moving visual field and/or moving platform), Buatois et al. (2006) were able to distinguish between multiple fallers and non-fallers. It is interesting to note that neither of these studies used narrow base stance during static posturography. These studies suggest that simple posturography may not be sensitive enough to discriminate balance disparities in healthy, independent, older adults.

To summarize, the one-item clinical tests of SLS and tandem stance have been correlated with future falls; however, it appears that a battery of clinical tests may be more discriminating than a single test alone. Balance tests such as the Tinetti POMA and the Berg Balance Scale have been developed for the assessment of frail older adults. When using these tests in healthy, physically active older adults there is a possibility that a ceiling effect may exist, especially considering the short duration (5-10 seconds) of timed clinical tests. The Fullerton Advanced Balance Scale may be more appropriate for active older adults. Compared to clinical measures, posturography may provide a more sensitive assessment of balance performance; in particular, indicators of mediolateral sway have been identified as possible predictors of future falls. The use of more challenging conditions, such as narrow base stance or the SOT may be more appropriate for healthy, active populations.

**Mobility**

Gait velocity and stride length decrease with age (Oberg, Karsznia & Oberg, 1993; Ostrosky, VanSwearingen, Burdett & Gee, 1994; Steffen, Hacker, & Mollinger, 2002). Because many falls occur during walking, certain characteristics of the gait cycle may be useful in identifying risk for falls. Newstead, Walden, and Gitter (2007) examined the differences between two groups of older adults—fallers (at least one fall to the ground in the past year) and non-fallers. Fallers spent a greater percentage of the gait cycle in double leg
support, exhibited a shorter stride length, and decreased velocity and cadence than non-fallers. In addition, fallers demonstrated different strategies for obstacle clearance during walking such as slowed velocity, and taking several small steps just prior to the obstacle. In contrast, non-fallers tended to adjust by increasing step length to clear the obstacle. Poor performance on the Timed Up and Go (TUG) test has been associated with recurrent falling (Stel et al., 2003). Maki (1997), testing 75 older adults, suggested that increased stride-to-stride variability in the control of gait was associated with future falls, with variability of speed being the strongest predictor of future falls. Stride width was also associated with future falls.

The relationship of static and dynamic balance to gait was investigated by Shubert, Schrodt, Mercer, Busby-Whitehead, and Guiliani (2006). In a cross-sectional study of community dwelling older adults (65-103 years old) they found a moderate correlation between static balance (tandem stance) and walking speed (r=.495), and a strong correlation between dynamic balance (360° turn) and walking speed (r=.701). Cromwell and Newton (2004) compared the Berg Balance Scale to walking velocity and gait stability ratio (cadence/velocity). A higher gait stability ratio indicates that a greater percentage of the gait cycle is spent in double-leg support. Although there was not a significant correlation between the total Berg Balance score and gait measures, there was a significant correlation between item 12, alternate stepping on a stool, and both walking velocity (r = .58) and gait stability ratio (r = -.74). Alternate stepping is a timed task requiring the subject to place alternate feet on a step stool for a total of eight steps. This dynamic balance task involves two components of the gait cycle: alternate leg movement and weight shifting. The association of this task to
the gait stability ratio adds evidence to support the correlation between measures of dynamic balance and gait.

In summary, clinical measures of mobility, such as the Timed Up & Go, and measures of dynamic balance, including the 360° turn and alternate stepping have been related to gait performance. These single-item tests may provide a simple measure for assessment of mobility and fall risk; however, gait analysis may be a more sensitive measure, especially for active older adults. A slowed velocity, decreased cadence and stride length, and a greater percentage of the gait cycle spent in double support have been related to future falls. Increased variability of these measures may also be suggestive of fall risk.

**The Effect of Physical Activity on Balance Regulation**

**Overview**

Incorporating physical activity into the lifestyle of older adults has the potential to reduce the risk of falls and fractures. Most research indicates that regular participation in physical activity has a positive impact on balance. Gregg, Pereira, and Caspersen (2000) suggest that physical activity exerts its protective effect through several attributes (Fig 1). Depending on the type of activity being practiced, physical activity may lead to improvements in the cardiovascular, musculoskeletal, and neuromuscular systems. Risk factors such as strength, coordination, balance, and mobility appear to be most directly influenced through improvements in the musculoskeletal and neuromuscular system. By reducing fall-related risk factors, physical activity may reduce falls and fractures. Weight bearing exercise reduces the risk of fractures through its contribution to the maintenance of bone strength and density. It is important to consider that physical activity may have long
Figure 1. Potential Impact of Physical Activity on the Risk for Falls and Fractures

Mechanisms/Attributes

Physical Activity (e.g. resistance, weight-bearing aerobic, balance)

- Energy Expenditure
  - Cardiovascular/Aerobic
  - Neuromuscular
  - Musculoskeletal

Risk Factors

Positive fall-related factors
- ↑ Strength & lean mass
- ↑ balance
- ↑ coordination
- ↑ mobility

Negative fall-related factors
- ↑ acute fatigue
- ↑ time at risk
- ↑ environmental exposure (stairs, footwear, objects)

Bone-related factors
- ↑ bone mineral density
- bone architecture

Outcomes

- Falls
- Hip & wrist fractures
- Vertebral fractures

1Gregg et al., 2000.
term protective effects against falls and fractures while at the same time increasing the short-term risks. Acute risk for falls increases during physical activities such as walking, climbing stairs, biking, or other sporting activities, suggesting the need for safety in implementing exercise interventions in older adults.

One risk factor Gregg et al. (2000) failed to include in their model is cognitive health. Physical activity in older adults has been shown to have a positive impact on cognitive functioning and, indirectly, may reduce the risk for falls. A 2003 meta-analysis by Colcombe and Kramer showed a moderate effect size (.478) for exercise interventions on overall cognitive scores as compared to a small effect size (.164) in control groups. Notably, the largest benefits from exercise were seen in executive control processes (effect size .68). Executive control processes describe brain processes used to direct thoughts and behavior in relation to internally-generated goals and are often used to override or inhibit automatic responses. Selective attention and decision-making are considered executive control processes.

The ability to recover balance after an external perturbation is more attentionally demanding for older adults than younger adults (Brown, Shumway-Cook & Woollacott, 1999). In addition, older adults may find it more difficult to divide attention between multiple tasks. Brauer, Woollacott and Shumway-Cook (2002) found that for both young and older adults, reaction times and movement initiation were longer in a dual-task situation (when a secondary cognitive task, counting backwards, was performed concurrently with a stepping movement) as compared to a single-task situation (stepping alone). In both conditions, older adults had slower reaction and movement times than younger adults; however, these differences in performance became more pronounced in balance-impaired older adults. Dual
task situations, such as carrying on a conversation while crossing a street, or carrying a load of laundry while walking down the stairs, occur often in everyday life. Because of the reduced attentional capacity of older adults, these situations may pose a greater risk for falls. Therefore, the effects of regular exercise on cognitive health may have an indirect influence on the reduction of falls.

**General Physical Activity**

A meta-analysis of the Frailty and Injuries: Cooperative Studies of Intervention Techniques trials (Province et al., 1995) showed that general exercise led to a significantly lower risk for falling in older adult populations (fall incidence ratio=.90). Those interventions that included specific balance-training components had an even lower fall incidence ratio of .83. Perrin, Gauchard, Perrot, and Jeandel (1999) found that the regular practice of physical activities such as walking, swimming, cycling, and yoga, had a positive impact on postural control as measured by static and dynamic posturographic tests. Those who had practiced physical activity throughout their life performed best in measures of postural control although those who had only recently started to incorporate physical activity into their lifestyle had scores that approached those of the lifelong group. In contrast, those who were active earlier in life, but had discontinued their practice showed less postural control than either of the currently active groups. Finally, those who had never practiced physical activities showed the poorest performance on measures of balance.

The effects of brisk walking on balance parameters were studied by Paillard, Lafont, Costes-Salon, Riviere, and Dupui (2004). Participants in the experimental group walked for 45-60 minutes, 5 days per week for twelve weeks. Compared to controls, statistically significant improvement was seen in dynamic balance as measured by mediolateral sway on
a moving platform, but no changes were seen in either static balance measured on a fixed platform or spatiotemporal gait measures. Federici, Bellagamba, and Rocchi (2005) explored the effects of dance-based training in subjects 58-68 years old. The dance group participated in a program of Caribbean dancing together with specific exercises for improving balance, while the control group met for social activities and games. After 3 months of training, the dance group showed maintenance or gains on four measures of balance compared to controls—the Tinetti Balance Scale, narrow stance time, tandem stance time, and TUG. Interestingly, the dance group also showed improvement on psychosocial measures of health such as sleep quality and reduction in smoking and alcohol consumption.

A variety of physical activities, including walking, swimming, dancing, yoga, and balance training, were investigated in these studies. In comparison to a sedentary lifestyle, engaging in some form of physical activity throughout a lifetime or later in life can positively affect balance.

**Multi-modal Physical Activity Programs**

In the case of balance and mobility, the nature of the benefit received from exercise may be dependent on the type of exercise performed. Shimada, Uchiyama, and Kakurai (2003), studied a population of frail, elderly adults (n=34) and compared the effect of balance exercises and gait exercises in two training groups and a control group. The training groups met for 40 minutes 2-3 times per week with the balance group practicing exercises with an emphasis on static balance such as multi-directional reaching and single-leg and tandem standing, while the gait group practiced exercises with an emphasis on movement such as walking, stair-climbing and tandem-walking. Both training groups showed significant improvements in physical function. Not surprisingly, the balance group showed the greatest
improvement in static balance measures (SLS, functional reach) and the gait group showed more improvement in measures of dynamic balance and mobility (Timed Up & Go, Tinetti POMA, stair climbing). This suggests that a multi-modal program of exercise might provide the greatest benefit for older adults wishing to reduce falls and preserve independent functioning.

Lord et al. (2003) assessed the effect of a 12-month, twice weekly multi-component exercise program in 280 older adults compared to a flexibility and relaxation control (n=90) and a no-exercise control group (n=181). The exercise program included aerobic, strength, balance, and flexibility exercises. The exercise group experienced 22% fewer falls than the combined control groups. This effect was more pronounced for those participants who had experienced a fall in the past year—this subgroup experienced 31% fewer falls. Functional measures of stepping and mobility improved in the exercise group while balance, as measured by postural sway, showed no significant differences between groups. This suggests that in this particular program, the exercises were not of sufficient intensity or specificity to produce gains in static balance. Similar findings were reported by Barnett, Smith, Lord, Williams, and Baumand (2003) after implementing a multi-modal, weekly, supervised exercise program with ancillary home exercises in a group of adults over 65 years of age. They found that rate of falls was 40% lower in the exercise group compared to controls. In addition the exercise group performed significantly better on three of six balance measures. In both the above-mentioned training programs, a significant decrease in falls was seen, supporting the evidence that exercise in general has a positive impact on reducing falls and may have a greater effect on dynamic balance than static balance.
Toulotte, Thevenon, and Fabre (2006) tested a small group of older women to measure the effect of resistance and balance training and de-training on static and dynamic balance. Participants engaged in a 12-week intervention involving resistance training and balance training. After training, both static (SLS) and dynamic balance (single- and dual-task gait measures) improved significantly. But after three months of detraining, the participants had returned to their pre-study levels. The authors of this study hypothesized that the improvement in balance was partially due to increases in muscular strength; however, it is difficult to determine the magnitude of the effect from resistance training alone, since other balance exercises were practiced during the study.

One problem with the study of multi-modal exercise programs is that it is difficult to judge the effect of the component parts. Programs including both aerobic and resistance training are beneficial for improvement in measures of balance when compared to stretching and relaxation exercises; however, specificity of training is an important consideration. Programs specifically focused on one component, such as gait or balance, lead to gains in their respective outcome measures. Physical activity provides a variety of health benefits and therefore, the use of multi-modal exercise programs allows for those benefits; however, in determining which components are the most beneficial for balance and falls reduction, it becomes necessary to look at more specific modes of exercise.

**Resistance Training**

In an effort to investigate which modes of exercise have the greatest effect on balance and mobility, many studies use walking or aerobic physical activity as a control for the effects of specific activities such as resistance training. Poor lower extremity strength is a factor contributing to disability in older adults (Guralnik et al., 1995). Chandler, Duncan,
Kochersberger, and Studenski (1998) implemented a 10-week strength-training program in frail, community-dwelling older adults using resistance bands and body weight for resistance. They noted that lower extremity strength gains led to improved performance in sit-to-stand, gait speed, and mobility tasks, but produced no significant changes in balance as measured by functional reach and postural sway on a force platform. A similar finding was seen in a group of moderately active older adults (Schlicht, Camaione, & Owen, 2001). Intense strength training three days per week produced a 20-48% increase in lower body strength and improved walking speed by 17% compared to a 6% increase in the control group; however, balance as measured by time in eyes closed SLS or sit-to-stand measures showed no significant difference between groups. Krebs, Jette, and Assmann (1998) implemented a 6-month home-based resistance training program using elastic bands for resistance in a population of older adults with one or more functional limitations (such as arthritis-related impairments). Pre- and post-intervention measures of strength and gait stability were administered in both the resistance-training group and a no-exercise control group. After the intervention, strength gains and gait stability were significantly higher in the resistance-training group compared to controls.

Simons and Andel (2006) compared a 16-week resistance-training program with a walking program of the same duration. This study of sedentary, independent-living older adults revealed improvements in upper and lower body strength as well as agility and balance in both experimental groups, suggesting a benefit from either form of exercise, but no significant advantages of resistance training over walking in improving balance parameters.

Some investigators have questioned whether resistance training to improve power rather than strength would have an impact on balance and other functional performance
measures. Quick reaction time, muscular activation, and movement speed may improve the likelihood of balance recovery after a perturbation. High velocity training to improve power was compared to a moderate walking program in healthy, high-functioning older adults (Earles, Judge, & Gunnarsson, 2001). The power-training group participated in lower-body training 3 days per week and included an additional 45-minutes of moderate exercise per week while the control group walked for 30 minutes, 6 days per week. Strength and power were measured using a pneumatic leg press machine. Balance and physical function were measured using a battery of tests including SLS, tandem stance, sit-to-stand, and the 6-minute walk. While both groups experienced an increase in strength, the power-training group showed a significant Group x Time effect for leg press power and peak power (increases of 22% and 150%, respectively). The 6-minute walk distance increased in both groups, however there were no significant effects on the balance measures in either group.

Orr et al. (2006) also measured the effects of high velocity power training in healthy older adults. Four groups of subjects included a control group, and low (20% 1RM), medium (50% 1RM), and high (80% 1RM) load training groups. Subjects trained twice weekly for 10 weeks. In order to train for power, each lift was performed with rapid concentric and slow eccentric action. Subjects training at low, medium, and high loads had equally significant increases in power with a dose-response increase in both strength and endurance when compared to controls. Balance was examined in two ways: 1) a balance index derived as a summary score of posturographic sway during both dynamic balance (moving platform) and static balance (SLS on a stationary platform), and 2) a loss-of-balance score. Interestingly, only the low load resistance training group showed significant improvements in the balance index and loss-of-balance scores. Since this was a high-velocity power training intervention,
those lifting lower loads experienced higher velocity while lifting than those using higher weight loads, suggesting that the speed of muscle contraction may be more important to balance than muscle strength or endurance.

The studies on resistance training suggest lower body strength gains may have a greater effect on gait measures and mobility rather than specific balance parameters such as SLS and postural sway. In addition, strength training may have a greater effect on balance improvement in frail older adult populations as compared to healthy older adults. Power training with the use of low-loads to allow for greater velocity may prove to be of benefit for balance improvement; however further study is warranted.

Balance Activities

In addition to general physical activity and resistance training, physical activities with a greater emphasis on sensory information have been studied in relation to balance. These proprioceptive activities include Tai Chi, non-sparring forms of martial arts, yoga, and balance-specific exercises such as one-legged standing, balancing with eyes closed or while moving the head, and standing or moving on unstable surfaces. These physical activities include gentle movements that are slower and rely more on proprioceptive feedback rather than external stimuli. The Frailties and Injuries: Cooperative Studies of Intervention Techniques trials that included a balance-training component resulted in a significant decline in falls (Province et al., 1995). Gauchard, Gangloff, Jeandel, and Perrin (2003) compared postural control in three groups of older women: those who practiced proprioceptive physical activities such as yoga or soft gymnastics (similar to non-sparring forms of martial arts), those who engaged in bioenergetic physical activities such as running, swimming, or cycling, and a control group of walkers. Measurements were taken on a force platform in both eyes.
open and eyes closed conditions. Both the proprioceptive and bioenergetic groups had significantly better balance control in the eyes-open condition than controls; however, the proprioceptive group showed better performance than either of the other groups in the eyes-closed condition, indicating less reliance on visual information and greater reliance on proprioceptive input in the regulation of balance. Similar findings were observed in a mixed gender population of elderly subjects (Gauchard, Jeandel, Tessier, and Perrin, 1999). Proprioceptive activities led to the greatest gains in balance control, while bioenergetic activities led to greater strength gains.

A twice weekly, 12-week exercise program designed to challenge sensory components resulted in significant improvements in static and dynamic balance and lower body strength (Islam et al., 2004). Exercises emphasized visual, vestibular, somatosensory and strength components including balancing with feet in various positions (together, tandem, single leg) while turning the head, reaching, and bending the body. All exercises were first practiced on the floor, progressing to standing on foam surfaces for a less stable base of support. The training group showed an 82% increase in SLS time with eyes closed. Limits-of-stability (dynamic balance) were measured on a force platform. In this test, the subject was asked to intentionally lean as far as they could in different directions without losing their balance. A greater leaning distance or maximum excursion indicates better dynamic balance. Training group subjects showed significant improvements in backward, left and right maximum excursion compared to the control group. Lower body strength as measured by the 30-second sit-to-stand, improved by 20% over baseline—significantly more than controls (5% improvement).
Sakamoto et al. (2006) looked at the effect of daily practice of one-legged standing on falls in nursing home residents (n=527). The intervention group practiced one-legged standing for 1 minute on each leg, three times per day (6 minutes total per day). After 6 months, there were significantly fewer falls in the intervention group (37 falls per 100 participants) when compared to the control group (57 falls per 100 participants). Using a group of older adults with a previous history of falls, Nitz and Choy (2004) compared an aerobic/strengthening exercise intervention to a specific balance-strategy exercise program that allowed for individual progression. After the intervention, both groups had a significant reduction in falls but no significant differences in measures of balance. These results should be interpreted with caution, however, since this study experienced an unusually high dropout rate with only 61% of participants completing the intervention and 44% returning for follow-up measures.

A number of researchers have examined the benefit of Tai Chi practice on balance regulation. Tai Chi is an ancient Chinese martial arts form incorporating intricate, dance-like exercise sequences with breathing and meditation. The movement in Tai Chi is slow and smooth and involves weight shifting, directional changes, and single-leg balance. Wolf et al. (1996) found that a 15-week Tai Chi intervention reduced the risk for multiple falls by 47.5% with a similar reduction in fear of falling. In contrast, a 48-week Tai Chi intervention in transitionally frail older adults led to significant reductions in fear of falling without a concomitant decrease in relative risk of falling (Sattin, Easley, Wolf, Chen, & Kutner, 2005). Li et al. (2005) demonstrated multiple benefits from a six-month Tai Chi intervention versus a stretching control. Improvements were seen in functional balance measures including the Berg Balance Scale, Dynamic Gait Index, Functional Reach, and SLS, as well as physical
performance measures including the Timed Up & Go and 50-foot speed walk. The risk for multiple falls was 55% lower in the Tai Chi group and fear of falling was significantly reduced. A six-month post-intervention follow-up showed that Tai Chi participants maintained better balance and physical performance scores, with 66% of participants reporting continued Tai Chi practice. Gatts and Woollacott (2006) showed improvements in similar measures of balance in a group of balance-impaired older adults after an intense Tai Chi training period consisting of 1.5 hours per day, 5 days per week for 3 weeks.

Cromwell, Meyers, Meyers, and Newton (2007) investigated the effect of Tae Kwon Do in older adults in comparison to controls. Tae Kwon Do uses long and wide stances combined with upper extremity movements. Participants move between stances and incorporate directional changes. After an 11-week Tae Kwon Do class, participants showed improvement in several measures of dynamic balance, including the Multidirectional Reach Test, Timed Up & Go, walking velocity, and time in single-limb support during walking. Certain yoga exercises also emphasize long, wide stances. An exploratory study of an Iyengar yoga program in older adults resulted in improved stride length and increased hip extension (DiBenedetto et al., 2005), suggesting a possible improvement in gait function; however this study only included eight subjects and no balance measures were taken.

Compared to other forms of exercise or no exercise, balance-specific training appears to have the most significant effects on measures of static and dynamic balance, but less impact on measures of gait. Outcome measures that test proprioceptive and vestibular control of balance show the greatest gains from balance-specific interventions, such as single leg standing, sensory training (such as the use of various balance surfaces or training with eyes closed or head movements), or Tai Chi and other forms of soft martial arts.
Overall Summary and Proposed Research

There is sufficient evidence to support the position that the regular practice of physical activity, regardless of type, will have some positive impact on balance and mobility, reducing the risk for falls. The inclusion of resistance training appears to lead to greater improvements in gait parameters, while the use of balance-specific exercises, including Tai Chi and other soft forms of martial arts, may have more influence on balance measures such as postural sway and static balance. High velocity power training may contribute to improved balance, including the possibility of improved response to perturbation, but requires further study.

By including cardiovascular, strength, and balance exercises into a regular program, multi-modal training may have advantages to any one type of exercise alone; however, current recommendations do not include a specific recommendation for balance training in older adults. In 1998 the American College of Sports Medicine (ACSM) issued a position stand recommending the use of a broad-based exercise program in older adults to enhance postural stability, including balance training, resistance training, walking, and exercises involving weight transfer (Mazzeo et al., 1998). The most recent recommendation from the ACSM and the American Heart Association (AHA) advises balance training for community-dwelling older adults with substantial risk of falls (Nelson et al., 2007).

Several questions emerge from these guidelines. First, should we wait to encourage balance training in older adults until they are at substantial risk of falls or is balance training also beneficial for older adults who are at a low risk of falls? Second, does meeting the guidelines for cardiovascular and strength training ensure good balance in older adults or will additional benefit be gained from balance training? Clinical balance trials have been
conducted over a wide range of physical performance capacities, from frail, institutionalized elderly to independent, community-dwelling, older adults. Few studies, however, define the physical activity level of their participants prior to the intervention, especially in regard to cardiovascular and strength activities. Therefore, it is unclear whether the addition of physical activity alone to a sedentary lifestyle has led to the improvement in balance or whether it is the balance training per se that has generated the improvement. In addition, there are no clinical trials comparing the effects of balance training on sedentary versus physically active older adults. Therefore, is unclear whether physically active older adults will benefit from balance training.

A third question relates to the exercise prescription: how often and how much balance training is needed to be beneficial? The ACSM/AHA guidelines give suggestions for frequency and duration of both cardiovascular and resistance training, but there are no guidelines for either the frequency or duration of balance training. Previous investigations have used varying frequency and duration of training, ranging from a single one-hour session per week (Nitz & Choy, 2004), or six minutes of one-legged standing per day (Sakamoto et al., 2006) to intensive training of 90-minutes per day, five days per week (Gatts & Woollacott, 2006), but none have compared varying doses within the same study. Moreover, there are no studies extant which specifically assess the dose-response to balance training. The most relevant one investigated the effect of exercise frequency on functional fitness, of which balance was one component (Nakamura, Tanaka, Yabushita, Sakai, & Shigematsu, 2007). Forty-five sedentary, older adult women were divided into three exercise intervention groups (90-minutes once, twice or three times per week) and a control group. The exercise intervention was multi-modal including cardiovascular exercise (walking), resistance training
(body weight and resistance tubing), and recreational activities that included balance, agility, and coordination training. The authors concluded that three, 90-minute sessions per week led to significant improvements in cardiorespiratory fitness (6-min. walk), muscular endurance (arm curl; sit-to-stand) and dynamic balance as measured by functional reach, and recommended an exercise frequency of at least three times per week for functional fitness. However, this study failed to take into account significant group differences in baseline values of functional reach. Moreover, it did not address balance-training dosage, since the intervention included multiple exercise components and only one outcome measure of balance. Also, this study was conducted with sedentary older adults, so the improvement may be secondary to general physical activity and not balance training per se.

In light of the relatively few studies on balance training in physically active older adults and no studies investigating dose-response of balance-specific training, the present study was designed to examine these questions. The hypothesis of this study stated that in a population of currently active adults over the age of 60, there would be an improvement in balance and gait measures after the addition of a six-week balance training program to regular physical activities. A secondary hypothesis was that there would be a dose-response relationship between the frequency of balance training and the level of improvement in balance control.
CHAPTER 3. METHODS

This was a randomized, controlled trial to investigate the effectiveness and dose-response pattern of two levels of balance training in healthy, physically active older adults. The intervention duration was six weeks and included a 3-day per week training group, a 1-day per week training group and a control group. Outcome data were collected at baseline and at the conclusion of the 6-week treatment phase. The institutional review board of Iowa State University approved the research protocol.

Participants

Sixty-three healthy, physically active, community dwelling adults volunteered to participate in the study. They were recruited from the Exercise Clinic at Iowa State University in Ames, Iowa, and the Lifetime Fitness Center in Story City, Iowa. To qualify for inclusion in the study, volunteers had to be 60 years or older and currently physically active. The latter was defined as participating in aerobic physical activity 3 days per week for at least 30 minutes and strength training exercises at least 2 days per week. Exclusion criteria included known neurological problems, unstable cardiopulmonary condition, uncontrolled high or low blood pressure, use of lower limb orthotics or walking aids, significant problems with joints or muscles that affect mobility, or recent (within 6 months) lower body bone fracture or total knee or hip replacement.

Two people did not meet the inclusion criteria. Therefore 61 people (24 men, 37 women) from 60-87 years of age (mean age = 72.9) were pseudo-randomized into three groups: control (n = 19), 1-Day (n =21), or 3-Day (n = 21), such that age and pre-test scores of SLS, alternate stepping and modified Berg Balance Scale scores were similar between
groups. Table 2 shows baseline characteristics of subjects at pretest. A one-way ANOVA on baseline characteristics revealed no significant differences between groups. Sixty of the 61 participants completed the study. One subject in the 3-Day group discontinued participation in the study during week 2 for health reasons; therefore, data for this subject were excluded from statistical analyses.

After being informed of the study protocol and prior to the start of the study, the participants signed an informed consent and completed a medical history form, including information about past and current physical activity, and medication usage.

### Table 2. Baseline Characteristics*

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Control (n=19)</th>
<th>1-Day (n=21)</th>
<th>3-Day (n=20)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>71.7 ± 7.7</td>
<td>72.3 ± 7.7</td>
<td>74.4 ± 6.8</td>
<td>.512</td>
</tr>
<tr>
<td>BMI</td>
<td>25.9 ± 3.9</td>
<td>27.2 ± 3.9</td>
<td>25.5 ± 2.7</td>
<td>.309</td>
</tr>
<tr>
<td>SLS-Right</td>
<td>24.3 ± 17.7</td>
<td>18.7 ± 12.2</td>
<td>21.5 ± 14.2</td>
<td>.499</td>
</tr>
<tr>
<td>SLS-Left</td>
<td>20.9 ± 16.6</td>
<td>16.3 ± 11.9</td>
<td>16.4 ± 14.0</td>
<td>.526</td>
</tr>
<tr>
<td>Alternate Stepping</td>
<td>7.5 ± 1.1</td>
<td>7.9 ± 1.8</td>
<td>8.2 ± 1.6</td>
<td>.417</td>
</tr>
<tr>
<td>Modified Berg</td>
<td>27.3 ± 1.3</td>
<td>26.7 ± 1.8</td>
<td>27.4 ± 1.2</td>
<td>.293</td>
</tr>
<tr>
<td>Balance Scale</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Reported as mean ± standard deviation

### Intervention

Subjects were pseudo-randomized into one of three groups with groups matched for age, gender, time in SLS, alternate stepping time, and modified Berg Balance Scale. Eight husband-wife couples were involved in the study and these subjects were randomized as couples so that they could participate in the same intervention group. The 3-day per week group (n=20; 11 women, 9 men) participated in 20 minutes of balance training three days per week for a total of 60 minutes per week. The 1-day per week group (n=21; 13 women, 8 men) participated in one 20-minute session of balance training per week and the control group (n=19; 12 women, 7 men) did not participate in any additional balance training. All
participants were instructed to continue with their regular exercise routine with the balance training taking place in addition to the subjects’ regularly scheduled exercise routine. All groups were asked to avoid additional balance training practice outside of their scheduled training sessions. Control and 1-day per week participants were offered the same 6-week balance training session (3 sessions per week) at the conclusion of the study. Classes were held in the Forker Building at Iowa State University for ISU participants and at the Lifetime Fitness Center for Story City participants.

A progressive balance training program was developed using components of the Fall Proof program developed by Rose (2003). A physical therapist, experienced in working with older adults, assisted in the development of the program. The same instructor led all balance-training sessions. This instructor was a Certified Health & Fitness Instructor-ACSM and a certified Tai Chi for Arthritis instructor. Upper level kinesiology undergraduate students assisted as spotters during the training sessions. Six balance sessions were developed with the level of challenge increasing with each successive session. During each week of the training, a new, progressively more challenging session was presented. The 1-day per week group participated once in this session, while the 3-day per week group repeated the same session three times over the course of the week. This way, all participants experienced the same balance exercises, but in varying doses. Each training session began with 4-5 minutes of Sun Style Tai Chi, as outlined in the Tai Chi for Arthritis program developed by Lam (2004). Balance training consisted of exercises to train both static and dynamic balance as well as mobility in both single and dual-task conditions. Exercises were designed to challenge visual (eyes opened, eyes closed), vestibular (head movement), and somatosensory (standing on various balance surfaces) systems and included single-leg stances, narrow stances, tandem
and semi-tandem stances, tandem walking, walking on foam surfaces, obstacle crossing while walking, weight shifting, and reaching to limits-of-stability. Examples of dual task conditions include single-leg stances while moving the head, reading aloud, or tossing an object, and walking while performing other tasks (see Appendix A for a menu of exercises and progression).

Adherence to the balance-training program was excellent (99.6%) with only two participants missing one session each. A total of 16 sessions were offered each week (12 at Iowa State University and 4 at the Lifetime Fitness Center). Participants could choose which training session(s) to attend each week, with the 1-Day group attending only one session per week and the 3-Day group attending three sessions on three separate days (usually non-consecutive days). Most participants completed the balance training immediately following their regular workout session. If participants were unable to attend one of the regularly scheduled sessions, make-up sessions were arranged so that program adherence was maintained.

**Outcome Measures**

Measurements were taken at two time periods: within the two weeks prior to the start of the intervention, and between 4-10 days after the conclusion of the subject’s last balance training session. Clinical outcome measures included a modified version of the Berg Balance Scale, and timed measures of SLS, tandem stance, 360° turn and alternate stepping. Laboratory outcome measures included posturographic measurements and a gait analysis. All participants also completed the Activities-Specific Balance Confidence scale (ABC) pre and post intervention.
Clinical Measures

Because the participants in this study were already active and had high functional fitness levels, a modified version of the Berg Balance Scale was used, including only the last 7 items of the original Berg Balance Scale: functional reach in centimeters, turning to look behind, retrieving an object from the floor, alternate stepping, 360° turn, tandem stance, and SLS. Each item on the Berg Balance Scale is scored from 0-4 with a score of 4 indicating the highest level of function. The maximum score for the 7-item modified Berg Balance Scale is 28. During the process of completing the modified Berg Balance Scale, alternate stepping and 360° turn were timed individually in addition to being scored on the modified Berg Balance Scale. Single-leg-stance and tandem stance were timed in stocking feet on the force platform.

Posturographic Measurements

Posturographic measures were taken using the AMTI biomechanics force platform model OR6-5 (Advanced Mechanical Technology, Inc, Watertown, MA). Eight conditions were tested in the following order: eyes-open narrow stance, eyes-closed narrow stance, single-leg-stance left (SLS-L), single-leg-stance right (SLS-R), limits-of-stability, tandem stance, foam-eyes-open narrow stance, and foam-eyes-closed narrow stance. All conditions were tested in stocking feet with subjects standing quietly with arms crossed over the chest and vision focused on a black circle placed 10 feet in front of them at eye level. Subjects stood with heels on a pre-marked line. After stepping on the platform, the foot position was marked so that the subject stood in the same position on the platform for each successive trial. For foam trials, a 4-inch thick piece of open cell foam was placed on the force platform.
and marked in the same manner as the force platform. Spotters were present during all force platform measurements. For double support stances including foam and limits-of-stability, subjects stood on the force platform in a narrow stance with feet touching. In eyes-closed conditions, subjects were asked to focus their eyes forward and when ready, close the eyes. Measurement began as soon as the eyes were closed. Two, 30-second trials of each condition were sampled at a frequency of 50 Hz.

Single-leg-stance (SLS) was measured on each leg with the eyes open. The subject was instructed to lift one foot to the height of the opposite ankle with the knee flexed and the lifted foot held next to the support leg without touching it. Timed scores were recorded as the number of seconds the subject was able to stand on one foot without putting their other foot down or touching the lifted foot or leg to the support leg. Although subjects were timed for up to 45 seconds, posturography was measured for only 30 seconds. Since many of the subjects were not able to remain in SLS for 30 seconds, a lower cut off of 20 seconds was used in the posturographic analysis of SLS in order to have a larger population. Only those subjects with both a pre- and posttest of 20 seconds or more were included in the analysis (n=35, SLS-R; n=27, SLS-L). Two trials were completed on each leg and the best trial (or the first trial if both trials were > 35 seconds) was used in the posturographic analysis.

Limits-of-stability was measured by asking the subject to shift their weight as far as they could in a specified direction, without bending at the waist, hips, or knees, or losing their balance, and while keeping both feet with heels and toes on the platform. On the verbal command of the tester, the subjects were instructed to lean forward, backward, left and right, in that order. Subjects held each position until instructed to return their weight to the center
before leaning in the next direction. One practice trial of the limits-of-stability test was
allowed on the floor before completing two trials on the force platform.

Tandem stance was measured by having the subject stand heel to toe on a diagonal
tapeline placed on the force platform with the heel and toe touching in the center of the line.
Subjects were allowed to choose which foot they preferred to have in front and the same
forward foot was used on both trials. Subjects were asked to assume the position without
assistance. If they were unable to do so, the tester offered assistance and this was noted.
Measurement began once the subject indicated that they were stable in the position. Tandem
stance was timed for up to 45 seconds, with posturographic measurement lasting 30 seconds.

In a few of the force platform conditions including eyes-closed, limits-of-stability,
tandem, and foam-eyes-closed, some subjects were unable to remain in position for the full
30 seconds, or lost their balance and needed assistance. Only trials lasting 30 seconds, and
only subjects with both a pre and post trial of 30 seconds are included in the posturographic
analysis. Therefore, n=59 for eyes-closed; n=59 for limits-of-stability; n=52 for tandem; and
n=56 for foam-eyes-closed.

Variables measured include center of pressure sway velocity in both mediolateral
(ML) and anteroposterior (AP) directions, and 95% area ellipse. A difference score between
velocity in eyes-open and eyes-closed conditions (hard surface and foam) was calculated by
subtracting eyes-open velocity from eyes-closed velocity. For the limits-of-stability
condition, maximum center of pressure excursion in ML and AP directions was assessed.
The raw force-platform data were processed using custom MATLAB software (MathWorks,
Natick, MA). Data were smoothed using 4th order low-pass Butterworth filter with a cutoff
frequency of 8 Hz. Center of pressure data were then computed from the filtered data. All
calculations and equations used are described by Prieto, Myklebust, Hoffmann, Lovett, & Myklebust (1996).

Gait Analysis

Gait analysis was conducted using a 4.27-meter electronic walkway that measures temporal and spatial parameters of gait (GAITRite System, version 3.8, CIR Systems, Inc., Peekskill, NY). The participant was instructed to ambulate across a 7-meter course that included the electronic walkway. The start line was situated approximately 1.4 meters before the walkway and the end line was placed 1.4 meters after the end of the walkway. Three trials in each of two conditions—preferred walking pace and fast walking pace—were averaged for each condition. Participants were asked to stand on the start line and when directed, walk at a comfortable pace (or a fast pace) until they reached the end line. A spotter walked alongside the walkway for safety. Standard spatio-temporal gait parameters were measured including velocity, cadence, step length, width, and time, and percent time in double and single-limb support. Variability of velocity and step length was also investigated.

Statistical Analysis

Groups were compared using a repeated measures analysis of variance (ANOVA), Group (3) x Time (pre/post). Statistically significant differences between groups were located using the Bonferroni post hoc test. Alpha level was set at .05. In addition, percent change was calculated using the formula \[\frac{(\text{Posttest group mean} - \text{Pretest group mean})}{\text{(Pretest average of group means)}} \times 100.\]
CHAPTER 4. RESULTS

Clinical Measures

Table 3 lists pre- and posttest values (means and standard deviations) for selected clinical and gait variables, including p values for pre-test group differences and Group x Time interaction effects. A main effect for Time was seen for both SLS-L (F(1,57) = 15.6, p < .000) and SLS-R (F(1,57) = 18.10, p < .000). A significant Group x Time effect was also seen for SLS-L (F(2,57) = 4.28, p = .019) and SLS-R (F(2, 57) = 3.88, p = .026). All groups showed an increase in SLS times; however, on both left and right, the 3-Day group increased time in SLS more than both of the other groups. The 3-Day group showed a 62% improvement in SLS time on the left and a 48% improvement in SLS time on the right. Comparatively, the 1-Day group had a 22% and 23% improvement while the Control group had an 8% and 7% increase in SLS-L and SLS-R times respectively (Figure 2).

Figure 2. Percent Change for Single-leg-stance Times
There was a significant main effect for Time ($F(1, 57) = 30.49, p < .000$) with a strong trend for a Group x Time interaction effect for alternate stepping time ($F(2, 57) = 3.09, p = .053$). Again, the 3-Day group showed greater improvement than the other groups with a 24% decrease in time needed to complete 8 alternate steps compared to a 5% and 7% decrease for the 1-Day and Control group, respectively (Figure 3).

**Figure 3. Percent Change for Alternate Stepping Time**

Finally, there was a Group x Time interaction for ABC ($F(2, 47) = 7.31, p = .001$) in which the 3-Day and Control group showed an increase in confidence (2% and 1% respectively), while the 1-Day group experienced 1.5% decrease in confidence. A main effect for Time was observed for the modified Berg Balance Scale ($F (1, 57) = 7.03, p = .010$) with all groups showing a slight increase in scores from pretest to posttest.
Table 3. Summary of Clinical and Gait Results by Intervention Group*

<table>
<thead>
<tr>
<th>Variable**</th>
<th>Control n=19</th>
<th>1-Day n=21</th>
<th>3-Day n=20</th>
<th>p value§</th>
<th>Control n=19</th>
<th>1-Day n=21</th>
<th>3-Day n=20</th>
<th>p value†</th>
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<tr>
<td>SLS-Right (sec.)</td>
<td>24.3 ± 17.7</td>
<td>18.7 ± 12.2</td>
<td>21.5 ± 14.2</td>
<td>.499</td>
<td>25.8 ± 16.9</td>
<td>23.6 ± 16.8</td>
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<td>SLS-Left (sec.)</td>
<td>20.9 ± 16.6</td>
<td>16.3 ± 11.9</td>
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<td>.526</td>
<td>22.3 ± 14.7</td>
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<td>Alt. Stepping (sec.)</td>
<td>7.5 ± 1.1</td>
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<td>360° Turn (sec.)</td>
<td>2.3 ± 0.5</td>
<td>2.2 ± 0.5</td>
<td>2.5 ± 0.6</td>
<td>.454</td>
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<td>2.4 ± 0.4</td>
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<td>Tandem Stance (sec.)</td>
<td>42.9 ± 9.1</td>
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<td>.120</td>
<td>44.6 ± 2.0</td>
<td>38.9 ± 12.0</td>
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<td>.597</td>
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<td>Modified BBS (range 0-28)</td>
<td>27.3 ± 1.3</td>
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<td>27.4 ± 1.2</td>
<td>.293</td>
<td>27.6 ± 0.7</td>
<td>27.4 ± 1.1</td>
<td>27.5 ± 1.1</td>
<td>.261</td>
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<td>ABC (range 0-1600)</td>
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<td>1523 ± 83</td>
<td>1483 ± 113</td>
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<td>1566 ± 35</td>
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<tr>
<td>Preferred Velocity</td>
<td>137.8 ±18.3</td>
<td>130.8 ±15.1</td>
<td>129.3 ±16.6</td>
<td>.241</td>
<td>133.2 ±15.4</td>
<td>124.6 ±14.5</td>
<td>125.8 ±18.2</td>
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<tr>
<td>Preferred Cadence</td>
<td>115.8 ±9.3</td>
<td>113.6 ±8.6</td>
<td>111.5 ±8.1</td>
<td>.315</td>
<td>114.0 ±9.2</td>
<td>111.6 ±7.7</td>
<td>111.2 ±8.2</td>
<td>.691</td>
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<td>Fast Velocity</td>
<td>192.1 ±22.4</td>
<td>181.7 ±25.16</td>
<td>185.8 ±27.2</td>
<td>.428</td>
<td>202.0 ±28.4</td>
<td>189.1 ±24.0</td>
<td>191.9 ±30.2</td>
<td>.729</td>
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<tr>
<td>Fast Cadence</td>
<td>140.6 ±12.9</td>
<td>136.6 ±9.4</td>
<td>139.8 ±14.9</td>
<td>.557</td>
<td>146.0 ±16.7</td>
<td>141.9 ±10.6</td>
<td>144.9 ±17.0</td>
<td>.996</td>
</tr>
</tbody>
</table>

*Reported as mean ± standard deviation
**Average of two trials used for SLS-Right, SLS-Left; best score of two trials recorded for Alternate Stepping, 360° Turn, and Tandem Stance; average of 3 trials used for gait variables.
§One-way ANOVA of pre-test variables to identify baseline group differences
†Repeated measures ANOVA with pre test and posttest data (Group x Time interaction)
Posturography

Table 4 lists pre- and posttest values (means and standard deviations) for selected posturographic variables, including p values for pre-test group differences and Group x Time interaction effects. Of eight conditions measured on the force platform, significant intervention effects were seen in the eyes-open condition, the limits-of-stability condition and in the difference scores between the foam-eyes-opened and foam-eyes-closed conditions. A significant Group x Time interaction occurred for AP velocity in the eyes-open condition (F(2, 57) = 3.21, p = .048) with both intervention groups showing an increase in AP velocity while the control group showed a decrease. In the limits of stability condition, both a main effect for Time (F(1, 56) = 106.4, p < .000), and a Group x Time interaction (F(2, 56) = 3.52, p = .036) were observed for 95% area ellipse with both the 3-Day and the 1-Day groups showing a greater increase in area of sway than the Control group. The 3-Day and 1-Day groups experienced a 54% and 52% change compared to a 28% change in the control group (Figure 4). Similarly, a significant main effect for Time (F(1, 56) = 68.5, p < .000) and a

Figure 4. Percent Change for Limits-of-stability 95% Area Ellipse

![Percent Change for Limits-of-stability 95% Area Ellipse](image-url)
Group x Time interaction, \((F(2, 56) = 4.97, p = .01)\) were observed for maximum excursion in the AP direction. Here the 3-Day group experienced a 25% change, the 1-Day group, a 17% change, and the control group, a 9% change (Figure 5). Main effects for Time were also observed for maximum excursion in the ML direction \((F(1, 56) = 39.4, p < .000)\), while a non-significant Group x Time trend \((F(2,56) = 2.64, p = .08)\) was observed with both training groups increasing excursion to a greater degree than the control group.

**Figure 5. Percent Change for Limits-of-stability AP Maximum Excursion**

A difference score was calculated by subtracting sway velocity (cm/s) in the foam-eyes-opened condition from the foam-eyes-closed condition. A significant main effect for Time \((F(1, 53) = 4.17, p = .046)\) and a Group x Time interaction \((F(2,53) = 5.31, p = .008)\) were seen in the mediolateral plane for this variable. Both the 3-Day and 1-Day groups showed a decrease in difference score, with the most dramatic decrease occurring in the 3-
Day group, while the Control group showed an increase in the foam-eyes-opened/foam-eyes-
closed difference score (Figure 6). In order to characterize the difference score, post hoc
analyses were run separately on ML velocity in the foam-eyes-opened and foam-eyes-closed
conditions. A significant Group x Time effect was seen for velocity in the foam-eyes-opened
condition \((F(2, 57) = 4.014, p = .023)\) with the 3-Day and 1-Day groups showing an increase
in velocity while the Control group showed a decrease. No significant effects were seen in
velocity in the foam-eyes-closed condition; however, a comparison of the mean differences
showed an increase in velocity in the control group compared to decreases in both
intervention groups.

**Figure 6. Percent Change in Foam-eyes-open/Foam-eyes-closed ML Sway
Velocity Difference Scores**
Table 4. Summary of Posturographic Results by Intervention Group*

<table>
<thead>
<tr>
<th>Condition/Variable**</th>
<th>Pre test</th>
<th>Post test</th>
<th>p value$</th>
<th>Control</th>
<th>1-Day</th>
<th>3-Day</th>
<th>p value†</th>
<th>Control</th>
<th>1-Day</th>
<th>3-Day</th>
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<td>EYES-OPEN</td>
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<tr>
<td>95% Ellipse (cm$^2$)</td>
<td>5.9 ± 2.4</td>
<td>7.8 ± 4.3</td>
<td>6.2 ± 2.8</td>
<td>.161</td>
<td>5.5 ± 1.9</td>
<td>7.4 ± 2.6</td>
<td>.725‡</td>
<td>5.8 ± 1.9</td>
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<td>Velocity-AP (cm/s)</td>
<td>6.1 ± 2.2</td>
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<td>6.5 ± 2.8</td>
<td>.866</td>
<td>5.7 ± 1.7</td>
<td>7.0 ± 3.2</td>
<td>.048</td>
<td>7.6 ± 3.6</td>
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<tr>
<td>Velocity-ML (cm/s)</td>
<td>7.0 ± 2.4</td>
<td>8.2 ± 2.9</td>
<td>7.7 ± 2.4</td>
<td>.344</td>
<td>7.8 ± 2.6</td>
<td>8.5 ± 2.6</td>
<td>.291</td>
<td>9.0 ± 3.2</td>
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<td>EYES-CLOSED</td>
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<tr>
<td>95% Ellipse (cm$^2$)</td>
<td>10.4 ± 5.4</td>
<td>16.2 ± 10.2</td>
<td>12.4 ± 9.4</td>
<td>.103</td>
<td>10.7 ± 5.1</td>
<td>14.7 ± 8.6</td>
<td>.736‡</td>
<td>11.7 ± 6.8</td>
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<td>Velocity-AP (cm/s)</td>
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<td>10.9 ± 7.8</td>
<td>11.8 ± 5.5</td>
<td>.824</td>
<td>12.7 ± 6.8</td>
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<td>Velocity-ML (cm/s)</td>
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<td>.899</td>
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<tr>
<td>95% Ellipse (cm$^2$)</td>
<td>8.9 ± 4.3</td>
<td>11.7 ± 7.4</td>
<td>10.2 ± 6.5</td>
<td>.371</td>
<td>8.9 ± 3.9</td>
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<td>Velocity-AP (cm/s)</td>
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<td>Velocity-ML (cm/s)</td>
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<td>.023</td>
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<tr>
<td>95% Ellipse (cm$^2$)</td>
<td>22.0 ± 9.7</td>
<td>33.1 ± 24.6</td>
<td>23.9 ± 9.2</td>
<td>.087</td>
<td>23.4 ± 10.9</td>
<td>26.6 ± 12.7</td>
<td>.229‡</td>
<td>23.1 ± 11.6</td>
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<td>Velocity-AP (cm/s)</td>
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<td>16.1 ± 6.8</td>
<td>15.4 ± 6.0</td>
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<td>15.9 ± 6.0</td>
<td>16.5 ± 6.4</td>
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<td>17.7 ± 7.4</td>
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<td>Velocity-ML (cm/s)</td>
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<td>21.3 ± 9.5</td>
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<tr>
<td>95% Ellipse (cm$^2$)</td>
<td>87.8 ± 31.3</td>
<td>79.8 ± 27.8</td>
<td>82.9 ± 30.4</td>
<td>.706</td>
<td>111.3 ± 40.4</td>
<td>123.1 ± 38.7</td>
<td>.036‡</td>
<td>127.8 ± 42.3</td>
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<tr>
<td>Max Exc-AP (cm)</td>
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<td>6.5 ± 1.3</td>
<td>6.3 ± 1.4</td>
<td>.567</td>
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<td>7.6 ± 1.3</td>
<td>.010</td>
<td>7.9 ± 1.3</td>
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<td>Max Exc-ML (cm)</td>
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<td>5.3 ± 1.0</td>
<td>.728</td>
<td>5.6 ± 1.2</td>
<td>6.0 ± 1.1</td>
<td>.080</td>
<td>6.1 ± 0.9</td>
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</tbody>
</table>

*Reported as mean ± standard deviation

**Average of two trials

§One-way ANOVA of pre-test variables to identify baseline group differences

†Repeated measures ANOVA with pre test and posttest data (Group x Time interaction)

‡p value based on log transformation of 95% Ellipse
Gait Analysis

No significant intervention effects were seen in any gait outcome measures. Interestingly, there was a significant main effect for Time for velocity. From pre- to posttest, all groups showed a decline in gait velocity in the preferred walking condition (F(1, 57) = 5.15, p = .027) while exhibiting increased velocity in the fast walking condition (F(1, 57) = 15.28, p < .001). In addition, in the fast walking condition all groups showed increased cadence (F(1, 57) = 18.82, p < .001) and percent time in single stance (F(1, 57) = 9.46, p = .003). Selected pre- and posttest values for gait variables are listed in Table 3.
CHAPTER 5. DISCUSSION

The first objective of this study was to ascertain whether balance training would improve balance and gait measures in physically active older adults. The data from the present study support the hypothesis that physically active older adults can improve balance measures through the addition of balance training to their current exercise program. However, the data do not support the hypothesis that additional balance training will improve measures of gait. The second objective of this study was to determine if there was a dose-response to balance training. Findings from the current study are mixed with some variables reflecting a dose-response, while others do not.

Single-leg-stance time showed the most marked improvement of all clinical variables (Figure 2). The 3-Day group experienced a 62% and 48% change in SLS-L and SLS-R, respectively, with an average increase of approximately 10.7 seconds. In comparison, the 1-Day group had a respective change of 22% and 23% (average increase 4.3 seconds) while the control group had an 8% and 7% percent change (average increase 1.5 seconds). These data suggest that there is dose response effect of training on SLS.

It is interesting that the average pretest SLS time (best left & right combined) for the entire study population was 23.6 seconds. This is higher than reported by many studies of balance in elderly subjects. In a balance training study of frail elderly adults, 67-91 years of age, Shimada et al. (2003) reported average pre-intervention SLS times of 3.8 seconds. Community-dwelling adults ages 70-92 who participated in a Tai Chi training study had average pre-training SLS times of 6.9 seconds. Robitailie et al. (2005) reported pre-training SLS times of 13.3 seconds in a population aged 60-91 years of age. Hu and Woollacott
(1994) reported an increase in SLS time of approximately 3 seconds after training in a group of older adults; however they did not report the actual duration of SLS.

Similar pre-training SLS times to the current study were reported in the Tae Kwon Do study conducted by Cromwell et al. (2007). Average pre-training SLS time was 19.9 seconds, with the intervention group experiencing an average increase of 10.2 seconds after training. This study included independent community-dwelling adults; however, it is unclear how physically active the subjects were prior to the study as activity levels were not reported. The age of participants in the study by Cromwell et al. (2007) was similar to the current study with an average age of 72.7 years (range 60-83). This younger average age may contribute to longer SLS times.

Single leg standing is an important part of the gait cycle and many functional activities such as stair climbing or clearing an obstacle during walking. One-leg standing balance decreases with age (Bohannon et al., 1984) and poor performance in this task has been suggested as a marker of frailty and a potentially useful predictor of functional decline (Drusini et al., 2002). A measurable decline in balance may occur as early as the fifth decade of life (Isles et al., 2004; Nitz et al., 2003) with a marked decline occurring between ages 75-80 (Era, Heikkinen, Gause-Nilsson, & Schroll, 2002); consequently, the ability to improve or maintain SLS time through balance training, even among highly functioning older adults, may assist in slowing the rate of functional decline.

Single leg standing was an integral component of the balance training intervention. Each session incorporated at least two exercises involving single leg standing, including quiet SLS in both eyes open and eyes closed conditions, SLS while performing another task such as reading, tossing a ball, or moving the lifted leg, and SLS on a foam surface. All SLS
tasks lasted for 30-60 seconds per leg. The results of this study indicate that practice of single leg standing contributes to improved SLS performance and more practice leads to greater improvement.

The higher pre-intervention SLS times reported in the current study indicate that many balance assessment tools may not be sensitive enough to identify balance improvement in an active older adult population. Most balance assessment tools utilize maximum SLS cut-off times of 10 seconds or less. Many studies implement these standards when testing SLS. Vellas et al. (1997) reported that the inability to maintain SLS for 5 seconds was predictive of future injurious falls. The inability to remain in SLS for 5 seconds was considered a marker of frailty by Drusini et al. (2002). Topper, Maki, and Holliday (1993) used a 5-second cut-off for SLS as a part of an activity based balance assessment. A maximum SLS time of 10 seconds is used in the Berg Balance Scale (Berg et al., 1992) and the FICSIT-4 scale (Rossiter-Fornoff et al., 1995). The Fullerton Advance Balance Scale (Rose et al., 2006) uses 20 seconds for a maximum score in SLS and therefore, may be more discriminating for a physically active population; however more than half of the participants in this study (61%) were able to achieve at least one 20-second SLS time at pretest. Hurvitz et al. (2000) compared SLS time in fallers and non-fallers in an ambulatory outpatient setting. They included a younger population aged 50 and older and found that a SLS time of less than 30 seconds was associated with a history of falling, while a SLS time of greater than or equal to 30 seconds was associated with a low risk of falling. The fact that the 3-Day group in the present study was able to increase their SLS-right time to an average of 31.9 seconds is a significant finding in light of the associations reported by Hurvitz et al. (2000).
Alternate stepping time showed a strong trend toward improvement in the 3-Day group after training without a similar dose-response in the 1-Day group (Figure 3). A decrease in stepping time reflects an increase in the speed of stepping as this test measures how rapidly the subject can place alternate feet on a stool for a total of eight steps. The 3-Day group experienced a 24% change (a decrease in time to complete 8 alternate steps), while the 1-Day group had a 5% change and the Control group showed a 7% change. Alternate stepping is a measure of dynamic balance and requires rapid weight shifting from one leg to the other. Therefore alternate stepping may reflect mediolateral stability as well as movement speed.

The task of alternate stepping was practiced during only one of the six training sessions; however, other training sessions included activities such as stepping over obstacles that would likely have near transfer effects to alternate stepping. In addition, all balance training sessions began with Tai Chi practice. Fong and Ng (2006) compared response to perturbation in long-term Tai Chi practitioners, short-term practitioners, and non-practitioners. The long-term practitioners had significantly faster reflex times in both hamstrings and gastrocnemius muscles. Faster lower body reaction times might be associated with improved dynamic balance. Orr et al. (2006) suggested that speed of contraction might play a greater role in balance control than either muscle strength or power.

Another consideration is that the increased speed in alternate stepping in the 3-Day group may be partially accounted for by improvement in single-leg-stance times, as single leg balance is an integral component of stepping. Cromwell and Newton (2004) found a strong correlation between alternate stepping and gait stability ratio. Those who performed best on alternate stepping also had lower gait stability ratios, reflecting more time spent in
single leg support during walking. Cromwell et al. (2007) also found improved gait stability ratios in older adults after participation in a Tae Kwon Do intervention.

The ability to step rapidly may be beneficial in responding to perturbations and preventing falls. Brauer et al. (2000) tested the effectiveness of a reaction-time stepping test to predict fallers. Fallers exhibited a slower step time and movement time than non-fallers. Dite and Temple (2002) also found significant differences between elderly fallers and non-fallers in the step test, with fallers completing fewer steps than non-fallers in an allotted period of time. The decrease in alternate stepping time seen in the 3-Day group reflects improved balance control and may contribute to better responses when balance is disrupted.

In the force platform limits-of-stability condition, both training groups showed a greater increase in 95% area ellipse than the control group; however this improvement does not appear to be dose-related (Figure 4). To characterize the 95% ellipse area, maximum excursion in both planes was investigated. Both training groups showed a significant increase in maximum excursion in the AP plane compared to the control group and this increase reflects a dose response (Figure 5). In addition, maximum excursion in the ML plane showed a trend toward significance (p = .08), with both training groups showing a greater increase in ML maximum excursion when compared with the control group.

Islam et al. (2004) reported an increase in limits-of-stability maximum excursion in both AP and ML directions after a 12-week balance-training program. The increase in AP excursion was significant in the backward, but not forward direction. Similarly, Seidler and Martin (1997) reported an increased backward leaning distance in both fallers and non-fallers after a short-term balance-training program. Although response to balance training appears to lead to increases in maximum excursion during limits-of-stability testing, there is mixed
evidence as to whether limits-of-stability measures are related to risk of falling. Both Brauer et al. (2000) and Boulgarides et al. (2003) were unable to predict future falls using force platform limits-of-stability measurements in independent, community-dwelling older adults; however, Wallmann (2001) found a strong correlation between scores on the Sensory Organization Test (SOT) and forward leaning measures in the limits-of-stability test in community-dwelling adults over the age of 60. The SOT has been used in the prediction of future falls (Buatois et al., 2006).

In response to a perturbation, three strategies may be used to regain balance control; an ankle response where the feet remain in place and movement about the ankle leads to balance recovery; a hip response, where the feet remain in place and movement about the hip results in balance recovery; or a stepping response, where a step is required to regain balance control. In response to a perturbation, older adults predominately use a stepping response (60% of the time), whereas younger adults use this strategy much less in favor of using an in-place response, such as an ankle or hip strategy (Brown, Shumway-Cook, & Woollacott, 1999). When balance disruptions are experienced concurrent with a secondary cognitive task, the ability to recover balance may be further compromised. The stepping response appears to be more attentionally demanding than ankle or hip strategies (Brauer, Woollacott, & Shumway-Cook, 2002). If older adults are able to utilize an ankle strategy in response to a perturbation, there may be a greater likelihood of success in balance recovery, especially in dual-task situations.

The increase in maximum excursion during the limits-of-stability test may reflect an improved ability of subjects to utilize an ankle strategy in balance control. Ankle strategy was practiced in four of the six balance training sessions. Participants were instructed to
stand with feet together and shift their body weight in different directions, including both AP and ML while keeping both feet on the floor. In some instances, the face of a clock was visualized and subjects asked to shift their weight to hand positions on the clock. This strategy was practiced with both eyes open and eyes closed, on a hard surface and a foam surface. In addition, weight shifting was practiced in the AP direction while in tandem stance. Hip strategy was also practiced in three of the balance training sessions. The practice of feet-in-place strategies for balance control seems to have contributed to an increase in limits-of-stability in the training groups, especially in the AP direction.

Because the study population was highly functional, we hypothesized that posturography measures would prove more sensitive and thus more discriminatory of balance improvement than clinical variables. Like previous studies (Chandler et al., 1998; Lord et al., 2003; Nitz & Choy, 2004; Paillard et al. 2004) we found no significant effects of training on posturography measures in simple static conditions across time periods; however, by obtaining an eyes open/eyes closed sway velocity difference score in the foam condition, a significant interaction effect was seen in the ML direction. Both training groups experienced a decrease with the 3-Day group exhibiting a 52% change and the 1-Day group showing a 14% change. In contrast, the Control group exhibited an increase in difference scores with a 14% change in the opposite direction (Figure 6). In light of the functional status and physical activity levels of the subjects used in this study, it would seem logical that differences may not be seen until more sensitive conditions were investigated. The use of foam challenges the contribution of the somatosensory system to balance by decreasing the input of cutaneous receptors while increasing reliance on muscle and joint proprioception, as well as visual and vestibular inputs. In the eyes closed condition on a foam surface, the control of balance shifts
to vestibular and proprioceptive control. The difference between the eyes open and eyes closed conditions helps identify the contribution of vision to balance. A higher difference score signifies a greater reliance on vision, while a lower difference score suggests a greater contribution from vestibular and proprioceptive inputs.

Reliance on visual inputs in the control of balance increases with age, while at the same time there is a general reduction of visual functioning (Lord & Menz, 2000). Therefore, the contribution of other systems to postural control becomes increasingly important with age. Tanaka & Uetake (2005) measured postural responses in older adults on firm and foam surfaces in both eyes closed and eyes open conditions. They found that ML sway increased dramatically in the foam-eyes-closed condition and suggested that visual information plays an important role in the control of balance in the ML direction. In the present study, as a result of the intervention, both training groups experienced a significant increase in ML sway velocity in the foam-eyes-open condition, while showing a non-significant decrease in ML sway velocity in the foam-eyes-closed condition. The combination of these two changes led to a significant decrease in foam-eyes-opened/foam-eyes-closed difference scores in the ML direction. Interestingly, the control group demonstrated the opposite of the training groups with a decrease in ML sway velocity in the foam-eyes-opened condition and an increase in sway in the foam-eyes-closed condition, leading to an increase in difference scores.

The increase in ML sway velocity of the training groups during the foam-eyes-opened condition may be a result of the subjects’ feeling more confident while standing on a compliant surface as a consequence of exposure to this surface during practice. Standing on foam with the eyes closed poses a greater threat to posture than standing on foam with the eyes open. Brown, Sleik, Polych, and Gage (2002) measured postural sway area of subjects
in four conditions of postural threat (using high and low platforms). They found a greater sway during non-threatening conditions and a tightening of control (reduced sway) in the more threatening conditions. It is possible that the effects of practice increased the ability of the training groups to identify and respond to the more threatening foam-eyes-closed condition with tightened postural control, while feeling less threat in the foam-eyes-opened condition and thus allowing a greater sway velocity in this condition. It is also possible that the ability of the training subjects to incorporate ankle strategy may have contributed to greater sway velocity in the foam-eyes-opened condition.

The decreased sway demonstrated by the training groups in the foam-eyes-closed condition reflects a greater ability to utilize vestibular and proprioceptive control when visual inputs are removed. Gauchard, Jeandel, and Perrin (2001) investigated the contribution of visual and vestibular inputs to balance control in three groups of older adults, those who practiced proprioceptive physical activities such as yoga or soft gymnastics (similar to non-sparring forms of martial arts), those who engaged in bioenergetic physical activities such as running, swimming, or cycling, and a control group of walkers. Compared to the other groups, those who practiced proprioceptive activities demonstrated good vestibular sensitivity and less reliance on visual inputs for balance control. Another report involving the same population of older adults demonstrated that those who participated in proprioceptive physical activities utilized greater proprioceptive inputs in the regulation of balance (Gauchard et al., 2003). Thus, balance-specific training and proprioceptive activities such as Tai Chi appear to help train vestibular and proprioceptive systems for better control of balance. Each balance training session included 5 minutes of Tai Chi and at least three
exercises incorporating static or dynamic balance while standing on a foam surface, including exercises on foam with eyes closed.

Although the 3-Day and the 1-Day group showed increased SLS time, there were no significant differences in posturographic measures recorded during SLS. This may be partially due to the fact that many of the study participants were not able to maintain SLS for the minimum 20 seconds used for posturographic analysis at both pre-and posttest sessions, and therefore, the total number of analyses was smaller for this variable (n=35, right; n=27, left). Consequently, only high performers in each of the three intervention groups were analyzed using posturography in SLS. Another reason may be that individual time components of SLS may need to be measured separately. Jonsson, Seiger, and Hirschfeld (2004) measured postural steadiness in one-leg stance in both healthy young and elderly adults. The variability of ground reaction forces in relation to time was investigated in trials of SLS lasting 30 seconds. Two phases of SLS were identified. The first phase, the dynamic phase, comprised approximately the first 5 seconds of SLS and was characterized by a decrease in force variability. The second phase, the static phase, was characterized by a constant force variability level and comprised the final 25 seconds of the test. Force variability decreased more rapidly during the first 5 seconds of SLS in the younger adults and remained low during the static phase. In contrast, in older adults, force variability did not decrease as much or as rapidly during the dynamic phase and therefore, variability levels remained higher during the static phase. Thus, older adults had less postural stability in SLS due to a reduced ability to decrease force variability in the dynamic phase. The authors suggested that the first 5 seconds are crucial when assessing balance in SLS. It may be
prudent to conduct future analyses on data from the present study to ascertain differences in force variability during the first 5 seconds of SLS.

Both the 3-Day and Control groups showed an increase in balance confidence as reflected by higher scores on the Activities-Specific Balance Confidence Scale (ABC). The 3-Day group showed the greatest increase in ABC scores; however they started with the lowest scores and, with the increase in scores after training, their final scores were equivalent to the final scores of the Control group.

Unexpectedly, the 1-Day group showed a decrease in balance confidence scores after training. This was a progressive balance-training program with each session being more difficult and building upon what was practiced in the previous session. Those in the 3-Day group practiced the same session on three separate occasions before moving on to the next, more difficult training session. In contrast, the 1-Day group experienced only one 20-minute training session before being exposed to more difficult tasks during the next session. During the course of the intervention, some of the 1-Day participants communicated that the balance-training program brought them to an increased realization of their own balance limitations. In addition, others expressed frustration at not being able to master some of the skills before moving on to more difficult skills. It is possible that the lower balance confidence scores of the 1-Day group reflect an increased awareness of balance limitations because of training, and thus are an indirect effect of training. Future analyses of the current data comparing individual balance scores with ABC scores may be interesting.

No differences between groups after training were seen in gait variables in this study. The measurements of comfortable and fast walking may not have been sensitive enough to detect changes in such a high functioning population. Future studies might
investigate gait under more challenging conditions, such as during obstacle clearance.

Similarly, there were no differences in the modified Berg Balance Scale after training due to a ceiling effect. At pretest, the average score on the modified Berg Balance Scale was 27.1 out of a possible 28. At posttest, the group average score was 27.4. Clearly, the modified Berg Balance Scale is not sensitive enough for an active older adult population. The Fullerton Advance Balance Scale would be more discriminating in this population and may be a beneficial tool in balance assessment; however its use to measure change over time may be limited. The last item on the scale requires the subject to lean back into the tester’s hand. As the subject leans back, the tester removes his/her hand and observes the balance recovery strategy of the subject. Because this test requires the element of surprise, it may have limited use as a post-test measure.

This study had a few limitations. In the gait analysis, the main effect for Time in the fast walking condition may have been a reflection of slightly different verbal instructions given by the experimenters from pre- to post-testing. All posturographic and SLS tests were conducted by the same experimenter; however the gait analyses were conducted by more than one experimenter. During the course of pre-testing, it was discovered that some of the experimenters were using the word “brisk” while others were using the word “fast” to describe the walking speed for the fast walking condition. This was corrected for the remainder of the pretest and for the posttest. Since there is a difference between brisk and fast walking, the increased walking velocity, cadence, and percent time in single leg support in the fast condition at posttest may be a reflection of this change in the description of the task.
Pre-testing for this study began in mid-September. Many of the participants in this study are members of the Adult Exercise Clinic at Iowa State University. The fall session of the exercise clinic began in mid-August, so all Exercise Clinic participants had been exercising regularly in the clinic for at least one month prior to pretesting; however some subjects did not participate in the Exercise Clinic during the summer months, choosing alternative physical activities such as gardening and walking outside. Therefore, pretesting measures may have somewhat reflected summer conditioning. The training took place over a six-week period and post testing occurred in early November. By this time all Exercise Clinic participants had been regularly participating in the clinic since August. Hence, some of the improvements in both the Control and training groups may have been a reflection of the regular conditioning received in the Exercise Clinic during the fall months.

Another limitation may be that improvements in the training groups may, in fact, be a reflection of additional exercise in general. The 3-Day group received an additional 60 minutes of training each week, compared with 20 minutes for the 1-Day group and no additional training in the Control group. Perhaps exposure to more physical activity in general was enough to lead to improvements in some balance measures. Since this study was designed to investigate dose-response, unequal exercise exposure was to be expected; however future studies might include another form of physical activity such as stretching or breathing exercises for the 1-Day and Control groups so that all groups experience the same total training time per week.
Conclusion

Balance training in a group of physically active older adults led to improvements in measures of balance, but not in gait. It is unclear whether there was a dose-response to balance training. There appears to be a dose-response for SLS time and maximum AP excursion in the limits-of-stability test; however, none of the other variables of significance reflected a clear dose-response. After training, the 3-Day per week training group experienced the greatest improvement in balance measures compared to the control group including 1) significant increases in SLS times on both right and left legs, 2) a significant increase in 95% area of ellipse and maximum AP excursion in the limits-of-stability test, 3) a significant decrease in foam-eyes-opened/foam-eyes-closed difference score, 4) a trend toward significant improvement in alternate stepping time, and 5) an increase in balance confidence as evidenced by increased ABC scores. Compared to Controls, the 1-Day group experienced improvement in SLS time and limits-of-stability maximum AP excursion to a lesser extent than the 3-Day group, but showed similar improvement in the limits-of-stability 95% ellipse and foam-eyes-opened/foam-eyes-closed difference scores. The 1-Day group did not differ significantly from the Control group in alternate stepping, and actually experienced a decrease in balance confidence after training.

The results of this study suggest that active older adults who exercise regularly can benefit from the addition of balance training to their current exercise program. While the current ACSM/AHA recommendations advocate balance training for older adults at substantial risk of falls, this study suggests that those who are already physically active may benefit from regular balance training. The data indicate that three 20-minute sessions per week lead to the greatest improvement; however it appears that even one 20-minute session
of balance training per week leads to some improvement. Further research of balance training and dose-response in active older adults is needed to determine whether current recommendations for physical activity in older adults are adequate.
REFERENCES


## APPENDIX A: BALANCE-TRAINING PROGRAM

### Session 1

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Time</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Tai Chi toe taps/kicks</td>
<td>4 min</td>
<td>1) Beginning stance: heels together, toes turned out (duck feet), soft knees, hands in gentle upturned fist at waist. Movement: Weight shifts to R foot and L foot taps forward, return L foot to beginning stance and shift weight to L foot, R foot taps forward. Repeat. Advance movement by kicking foot forward rather than tap. Advance movement by adding opposite arm punch forward.</td>
</tr>
<tr>
<td>2) Tai Chi weight shifting forward</td>
<td></td>
<td>2) Beginning stance: same as above. Movement: Weight shifts to R foot as L foot steps forward, heel first, then toe. Weight shifts forward into L foot as knee bends over ankle. Keep right foot on the ground. Shift the weight back into the R foot and place the L foot back into beginning stance (like a forward lunge). Repeat on opposite side. Advance movement by adding opposite arm punch forward.</td>
</tr>
<tr>
<td>Single-leg-stance, Eyes open, hard surface</td>
<td>2 min</td>
<td>60 seconds standing on each leg. Cues: keep knees soft, focus eyes forward, if you need to tap foot down, pick it right back up, use touch only on handrail—don’t hold on if possible. For those who are stable, advance by bringing arms across chest or lifting leg higher</td>
</tr>
<tr>
<td>Walking on Toes/Heels, hard surface and foam</td>
<td>3 min</td>
<td>Begin by walking on gymnastics mats with regular steps. Walk on hard surface on toes across room and then across the mat. Walk on hard surface on heels then on the mats. Repeat by taking big steps on toes on hard surface, then mat, followed by big steps on heels on hard surface/mat.</td>
</tr>
<tr>
<td>Single-leg-stance, Eyes closed, hard surface</td>
<td>1 min</td>
<td>30 seconds on each foot. Close eyes prior to lifting leg. Use touch on handrail if necessary. If foot comes down, pick it right back up.</td>
</tr>
<tr>
<td>Tandem Stance and weight shifting</td>
<td>3 min</td>
<td>Assume tandem stance (heel to toe). Coach weight centering on heel of front foot and toes of back foot. Find focal point with eyes. Quiet standing for 30 seconds. Begin shifting weight into forward foot, then into back foot (3x). Advance by lifting back foot as weight shifts forward, lifting front foot as weight shifts back (3x). Repeat with opposite foot forward.</td>
</tr>
<tr>
<td>Crossover stepping (Grapevine step)</td>
<td>2 min</td>
<td>Face forward. Make sure the hips face forward as you step to the side, then cross leg behind, to the side, then cross leg in front. Repeat in opposite direction.</td>
</tr>
<tr>
<td>Narrow stance on foam with smooth pursuit eye movements followed by head movements</td>
<td>2 min</td>
<td>Standing on foam in narrow stance. Bring R hand in front of eyes, move hand to R and follow with eyes only. Return to center. Repeat with L hand (3x) Repeat same movements with hands, this time following with head movement (3x). Bring hand in front of eyes and raise hand up, then down following with eyes only (3x). Repeat same movements following hand with head movements (3x).</td>
</tr>
<tr>
<td>Single-leg-stance, eyes open on foam</td>
<td>1 min</td>
<td>30 seconds each leg.</td>
</tr>
<tr>
<td>Ankle strategy between two chairs</td>
<td>2 min</td>
<td>Stand between two chairs with feet together. Shift weight forward and back, movement coming from the ankle. Keep the body straight. Try to touch the hips to the chair. Repeat shifting weight side to side.</td>
</tr>
</tbody>
</table>
### Session 2

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Time</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tai Chi commencement form, opening &amp; closing hands, single whip.</td>
<td>4 min.</td>
<td>Please see descriptions in Tai Chi for Arthritis Handbook (Lam, 2004)</td>
</tr>
<tr>
<td>Single-leg-stance, Eyes open, hard surface</td>
<td>2 min</td>
<td>60 seconds standing on each leg. Cues: keep knees soft, focus eyes forward (coach eyes up, not down at floor), if you need to tap foot down, pick it right back up, use touch only on handrail—don’t hold on if possible. For those who are stable, advance by bringing arms across chest or lifting leg higher</td>
</tr>
<tr>
<td>Tandem walking Hard surface &amp; Foam</td>
<td>3 min</td>
<td>Walk tandem (heel to toe) across room on hard surface, back on mat. Repeat. Coach looking forward rather than down. Touch heel to toe with each step.</td>
</tr>
<tr>
<td>Single-leg-stance, Eyes closed, hard surface</td>
<td>2 min</td>
<td>45 seconds on each foot. Close eyes prior to lifting leg. Use touch on handrail. If foot comes down, pick it right back up. If you feel dizzy, put foot down or hold rail until you feel steady. Keep the eyes closed if possible.</td>
</tr>
<tr>
<td>Tandem stance with head turns</td>
<td>2 min</td>
<td>Stand tandem 60 seconds. During last 30 seconds of tandem standing, cue head turns. (Head turns: right, center, left, center, left turning all the way to the right without stopping in the center). Repeat on with opposite foot in front. Cue head turns beginning left.</td>
</tr>
<tr>
<td>Double leg stance on foam with multi-directional reaching</td>
<td>2 min</td>
<td>Stand on foam (narrow stance for more challenge). Reach in all directions—forward, to each side, up &amp; diagonal forward each side.</td>
</tr>
<tr>
<td>Tandem stance/ Foam surface</td>
<td>2 min</td>
<td>Stand tandem on foam balance pad, 30 seconds each leg in front.</td>
</tr>
<tr>
<td>Single-leg-stance, move a towel with lifted foot</td>
<td>2 min</td>
<td>Stand on one foot. With other foot, push a towel forward, to the side and back. Keep the weight in the leg that is NOT pushing the towel. Repeat 3 times—on the third time, lift the foot off the towel at each position. Repeat on the opposite leg.</td>
</tr>
<tr>
<td>Ankle strategy with eyes closed</td>
<td>2 min</td>
<td>Stand between two chairs, feet in narrow stance. Keeping full foot on floor lean forward and then back, trying to touch hips to the chair. Repeat while leaning side to side. The legs should be straight (not locked), so movement is coming from the ankle. Practice once or twice with eyes open, then close eyes. Sixty seconds each side to side, then forward and back. Make sure chairs are close enough to receive feedback when hips touch chair.</td>
</tr>
<tr>
<td>Walking with head turns/abrupt starts/stops, changing pace</td>
<td>1 min</td>
<td>Walk at preferred pace turn head side to side on command. Repeat at fast pace. Walk at preferred pace tilting head up and down. Repeat at fast pace.</td>
</tr>
</tbody>
</table>
# Session 3

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Time</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tai Chi waving hands in cloud</td>
<td>4 min</td>
<td>Repeat single whip from week 3. From single whip add waving hands in clouds. Please see Tai Chi for Arthritis Handbook (Lam, 2004)</td>
</tr>
<tr>
<td>Single-leg-stance, Eyes open, hard surface with head turns</td>
<td>2 min</td>
<td>60 seconds standing on each leg. Cues: keep knees soft, focus eyes forward (coach eyes up, not down at floor), if you need to tap foot down, pick it right back up, use touch only on handrail—don’t hold on if possible. Try to spend as much time as possible on one leg with no assistance. During last 30 seconds, coach head turns—right, left, up, down.</td>
</tr>
<tr>
<td>Walking on hard surface &amp; foam while tossing bean bag</td>
<td>2 min</td>
<td>Walk first on hard surface, tossing beanbag between hands. Follow the beanbag with the eyes. Repeat while walking on gymnastics mats. Continue tossing the beanbag walking on hard surface, following the beanbag with small head turns. Repeat on foam surface.</td>
</tr>
<tr>
<td>Tandem Stance, Eyes closed, hard surface</td>
<td>1 min</td>
<td>30 seconds each foot in front. Feet in position first, center weight, then close the eyes. Use touch on handrail.</td>
</tr>
<tr>
<td>Single-leg-stance, moving lifted leg</td>
<td>2 min</td>
<td>Stand on right foot. Lift the left knee. Extend and bend the left leg (about 20 seconds), then change the direction of the moving leg by swinging it side to side in front of standing leg (20 seconds—total per leg = 45 seconds). Repeat with opposite leg.</td>
</tr>
<tr>
<td>Comfortable and narrow stance on foam with beanbag toss</td>
<td>2 min</td>
<td>Comfortable stance on foam pad, tossing beanbag from hand to hand. Follow beanbag with the eyes-30 seconds, then with small head turns-30 seconds. Repeat with feet in narrow stance.</td>
</tr>
<tr>
<td>Tandem stance, foam surface with multi-directional reaching</td>
<td>2 min</td>
<td>Stand tandem on foam pad; reach in multiple directions—forward, right, left, down to the right, down to the left. Repeat with other leg in front.</td>
</tr>
<tr>
<td>Single leg standing on foam</td>
<td>1 min</td>
<td>30 seconds each leg</td>
</tr>
<tr>
<td>Step strategy forward and back</td>
<td>2 min</td>
<td>Lean forward until limit of stability is reached and then take a step—first with the right, then with the left leg. Lean forward into the toes without a lot of bending at the waist. Look straight ahead as you step. Repeat stepping in the backward direction. Lean back through the hip (not from the head) before initiating the step. 60 seconds in each direction.</td>
</tr>
<tr>
<td>Walking backward on hard surface and foam</td>
<td>2 min</td>
<td>Walk backward on hard surface. Then walk backward on foam. Repeat. (2 passes on each surface)</td>
</tr>
</tbody>
</table>
## Session 4

<table>
<thead>
<tr>
<th>EXERCISE</th>
<th>TIME</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tai Chi-6 basic movements</td>
<td>4 min</td>
<td>Please see Tai Chi for Arthritis Handbook (Lam, 2004).</td>
</tr>
<tr>
<td>Single leg standing-VOR (vestibulo-ocular reflex) training</td>
<td>2 min</td>
<td>Stand on one leg, facing wall with eyes focused on colored sticky note—65 seconds total each leg. During the last 35 seconds on each leg move head side to side while keeping eyes on sticky note. Then move head up and down while focusing on sticky note (move head faster or wider movement for more challenge).</td>
</tr>
<tr>
<td>Ankle strategy around the clock on hard surface</td>
<td>1.5 min</td>
<td>Stand in narrow stance. Keep body straight so movement is coming from the ankle. When leader calls out a clock position, shift the body weight to that position. Example: 12 o’clock-lean as far forward as you can—weight moves into the front of your feet.</td>
</tr>
<tr>
<td>Forward walking and crossover stepping on heels/foots both on hard surface and on mat</td>
<td>3 min</td>
<td>Walk forward on toes hard surface-then on the mat. Walk forward on heels on hard surface-then on the mat. Crossover step on toes, hard surface—then on the mat. With crossover stepping, turn halfway through the exercise so you lead with the opposite foot. Alternative to crossover stepping is side stepping without crossing over.</td>
</tr>
<tr>
<td>Tossing bean bag to a partner while standing on one leg</td>
<td>2 min</td>
<td>With a partner, toss the beanbag. Each person is standing on one leg while both tossing and catching. Try to put the foot down as little as possible. 45 seconds on each leg.</td>
</tr>
<tr>
<td>Ankle strategy around the clock on foam</td>
<td>1.5 min</td>
<td>Same as above, only standing in narrow stance on foam.</td>
</tr>
<tr>
<td>Tandem on foam with head turns</td>
<td>1 min</td>
<td>Tandem standing on foam. Center the weight. Then turn head right, left, up, and down. 30 seconds each foot in front.</td>
</tr>
<tr>
<td>Eyes closed narrow stance on foam</td>
<td>1 min</td>
<td>Bring feet together on the foam. Close eyes and stand as quietly as possible for 30 seconds.</td>
</tr>
<tr>
<td>Walk tandem on half roller</td>
<td>1 min</td>
<td>Walk heel to toe on foam roller. Continue for one minute. Lead with alternate foot each time you step on the roller.</td>
</tr>
<tr>
<td>Standing on foam roller</td>
<td>1 min</td>
<td>Stand on foam roller, feet perpendicular to the roller. Stand quietly for 60 seconds</td>
</tr>
<tr>
<td>Hip strategy on the foam roller</td>
<td>1 min</td>
<td>Begin shifting the weight forward and back in the feet, forcing hip movement to stabilize.</td>
</tr>
<tr>
<td>Side stepping on foam roller</td>
<td>1 min</td>
<td>Side step across the roller and back.</td>
</tr>
</tbody>
</table>
### Session 5

<table>
<thead>
<tr>
<th>EXERCISE</th>
<th>TIME</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tai Chi-6 basic movements to the left</td>
<td>5 min</td>
<td>Same as six movements, but mirror to the left</td>
</tr>
<tr>
<td><strong>Single-leg-stance w/ reading task</strong></td>
<td>2 min</td>
<td>Lift foot and stand on one leg quietly for 15 seconds with eyes focused forward. At 15 seconds, instructor cues to begin reading. Continue to stand on one leg while reading tongue twisters aloud. Total of 60 seconds each leg.</td>
</tr>
<tr>
<td><strong>Tandem walking with head turns, direction changes, abrupt stops</strong></td>
<td>2 min</td>
<td>Walk tandem. When given verbal cue, turn head right, left, up, as you continue walking. When given cue, walk tandem backwards. When cued to stop, hold tandem stance.</td>
</tr>
<tr>
<td><strong>Ankle around the clock, hard surface, eyes closed</strong></td>
<td>1 min</td>
<td>Stand in narrow stance. Keep body straight so movement is coming from the ankle. Close the eyes and keep them closed. When leader calls out a clock position, shift the body weight to that position. Example: 12 o’clock-lean as far forward as you can—weight moves into the front of your feet.</td>
</tr>
<tr>
<td><strong>Single-leg-stance on foam, writing alphabet with other leg</strong></td>
<td>2 min</td>
<td>45 seconds each leg. Begin by lifting one foot and standing on one leg on the foam. Then, with the lifted foot, write the alphabet in the air.</td>
</tr>
<tr>
<td><strong>Alternate foot touches on step</strong></td>
<td>30 sec</td>
<td>Standing in front of a step with an 8 inch rise. Alternately tap foot on the step as fast as you can. Count how many you can do in 30 seconds.</td>
</tr>
<tr>
<td><strong>Obstacle course</strong></td>
<td>3 min</td>
<td>Three foam rollers taped together for tandem walking: Steps/Cones in this order: step, cones, step, 2 rows of cones, step, cones, step (step on the step and over the cones); Three foam rollers taped together for side stepping; Step throughs on 4 foam pads (step on pad, swing the other leg through). Evenly space the pads across the gymnastics mats. Take 2 steps in between each foam pad to make sure alternate legs are used on each step through. Navigate the course two times—make sure you side step on the foam rollers leading with opposite leg on second time.</td>
</tr>
<tr>
<td><strong>Single leg standing in stocking feet, hard surface</strong></td>
<td>1.5 min</td>
<td>45 seconds each leg</td>
</tr>
<tr>
<td><strong>Tandem standing in stocking feet, hard surface</strong></td>
<td>1.5 min</td>
<td>45 seconds each foot in front</td>
</tr>
</tbody>
</table>
### Session 6

<table>
<thead>
<tr>
<th>EXERCISE</th>
<th>TIME</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tai chi, 6 basic movements right &amp; left</td>
<td>5 min</td>
<td>Move once through the movements with verbal coaching, then complete the movements two more times to music with no verbal instruction—just follow the leader.</td>
</tr>
<tr>
<td>Single leg standing, arms crossed over chest</td>
<td>2 min</td>
<td>With arms across chest, lift one foot and stand on one leg. Make sure you don’t brace one leg against the other. Keep the eyes focused forward. Try to keep arms across the chest. If you need to stabilize yourself, touch the foot down and then lift it right back up so as to spend as much time on one leg as possible. 60 seconds each leg.</td>
</tr>
<tr>
<td>Varied walking while holding object</td>
<td>3 min</td>
<td>Holding a spoon with a plastic egg on it. As you walk, try to keep the egg from falling off the spoon. Walk forward the length of the room on toes, and then walk forward on heels. Turn to the side and cross step (grapevine) in each direction (left &amp; right). Tandem walk forward across the room, then backward.</td>
</tr>
<tr>
<td>Foam, hip circles, eyes open, eyes closed</td>
<td>1 min</td>
<td>Stand with feet together on foam pad, circle hips in one direction for about 8 seconds, then reverse the direction (about 15 seconds total with yes open); close the eyes and circle the hips in one direction for 15 seconds, then reverse directions for 15 seconds (30 seconds total with eyes closed)</td>
</tr>
<tr>
<td>Foam eyes open reaching with hands clasped. Eyes closed reaching</td>
<td>2 min</td>
<td>Stand on foam pad with feet together. Clasp the hands together and reach right, left, forward, up and right, up and left, down and right, down and left. The arms will cross the mid-line of the body as you reach. Separate hands and reach back with each hand individually. Close the eyes, clasp the hands and repeat all the movements (except backward reach) with eyes closed.</td>
</tr>
<tr>
<td>Tandem on foam, eyes closed</td>
<td>1 min</td>
<td>Stand heel to toe on the foam. Center your weight, then close the eyes--20 seconds each foot in front.</td>
</tr>
<tr>
<td>Single leg moving a ball with foot</td>
<td>2 min</td>
<td>Place a ball in front of the feet. Balance on one leg as you tap the other foot on the ball. With the lifted foot begin rolling the ball from toe to heel, and then make little circles with the ball, circling in each direction, then tap the ball forward, back to center, then out to the side—45 seconds on each leg.</td>
</tr>
<tr>
<td>Obstacle course with dual task</td>
<td>4 min</td>
<td>Navigate the same obstacle course as in week 5, but do so while holding a lunch tray with a cup on it. If possible hold the tray with both hands and try to keep the cup from tipping.</td>
</tr>
</tbody>
</table>
APPENDIX B. INFORMED CONSENT DOCUMENT

Title of Study: Does balance training improve balance in physically active older adults?

Investigators: Kristen Maughan, BS; Ann Smiley-Oyen, PhD.; Warren Franke, PhD.

This is a research study. Please take your time in deciding if you would like to participate. Please feel free to ask questions at any time.

INTRODUCTION

The purpose of this study is to study the effects of different amounts of balance training on walking and balance in older adults. You are being invited to participate in this study because you are an adult 60 years of age or older who is currently participating in regular physical activity at least three days per week.

DESCRIPTION OF PROCEDURES

If you agree to participate in this study, your participation will involve two or three one-hour testing sessions that are approximately six weeks apart. In addition, depending upon your group assignment, you may be asked to participate in six weeks of training, either one day per week or three days per week. Training involves a 20-minute balance session in the exercise clinic. During the study you may expect the following study procedures to be followed.

During each testing session, basic balance movements will be assessed, such as reaching forward, picking up an object from the floor, turning around, standing quietly on two feet with your eyes open and closed and standing on one foot with your eyes open. Lab assistants will be present to spot as needed. You will also be asked to walk across a carpeted walkway at both your preferred speed and then again at a fast pace. You will be given the opportunity to rest as needed. In addition, you will be asked to complete a medical history, balance and walking confidence questionnaires, and a questionnaire regarding your recent physical activity. You may skip any question that you do not wish to answer or that makes you feel uncomfortable.

If you are assigned to an intervention group, you will participate in a 6-week balance-training program. Sessions will be 20 minutes in length and you may be assigned to come one day per week or three days per week. During these sessions you will participate in light physical activities which will include two-legged and one-legged stances, standing and sitting on various surfaces, moving the head and performing simple tasks while standing or sitting on these surfaces. Modified tai chi and yoga postures will be included. At the conclusion of six weeks of training, you may be asked to continue your balance training once per week on your own time. If you are assigned to the control group you will not participate in the balance
training program, but will be asked to continue with your regular exercise program and participate in the testing sessions throughout the study. At the conclusion of the study, all control group and 1-day per week participants will be offered the full 6-week balance-training program.

RISKS

While participating in this study you may experience the following risks: There is some risk of loss of balance while walking, during the balance assessment, and during the balance training sessions. At all times during measurement sessions, a trained experimenter will walk or stand closely behind you to guard you. During the balance training sessions, the instructor and kinesiology students will be present to assist in exercise technique and to act as spotters. As with any new exercise, you may experience minor muscle soreness.

BENEFITS

If you decide to participate in this study there may be no direct benefit to you. Following the completion of the study, a letter will be sent to you with the results of your balance and walking assessments and you will receive written instruction describing the balance training exercises. It is hoped that the information gained in this study will benefit society by contributing to a better understanding how balance training affects balance regulation and mobility in older adults.

COSTS AND COMPENSATION

You will not have any costs from participating in this study. You will be compensated for participating in this study with free membership in the ISU Exercise Clinic. For each week that you participate in the study, you will receive one free week of membership to the ISU Exercise Clinic. You will receive the full semester at no charge at the completion of your final testing session.

PARTICIPANT RIGHTS

Your participation in this study is completely voluntary and you may refuse to participate or leave the study at any time. If you decide to not participate in the study or leave the study early, it will not result in any penalty or loss of benefits to which you are otherwise entitled.

RESEARCH INJURY

Emergency treatment of any injuries that may occur as a direct result of participation in this research is available at the Iowa State University Thomas B. Thielen Student Health Center, and/or referred to Mary Greeley Medical Center or another physician or medical facility at the location of the research activity. Compensation for any injuries will be paid if it is determined under the Iowa Tort Claims Act, Chapter 669 Iowa Code. Claims for compensation should be submitted on approved forms to the State Appeals Board and are available from the Iowa State University Office of Risk Management and Insurance.
CONFIDENTIALITY
Records identifying participants will be kept confidential to the extent permitted by applicable laws and regulations and will not be made publicly available. However, federal government regulatory agencies, auditing departments of Iowa State University, and the Institutional Review Board (a committee that reviews and approves human subject research studies) may inspect and/or copy your records for quality assurance and data analysis. These records may contain private information.

To ensure confidentiality to the extent permitted by law, the following measures will be taken.
Each participant will be assigned a unique code and this code will be used on forms and in data files. The data will be kept in the locked research lab and on a computer that will be accessible only to people working on the project. If the results are published, your identity will remain confidential.

QUESTIONS OR PROBLEMS
You are encouraged to ask questions at any time during this study.

• For further information about the study contact Dr. Ann Smiley-Oyen at 294-8261, or asmiley@iastate.edu.

• If you have any questions about the rights of research subjects or research-related injury, please contact the IRB Administrator, (515) 294-4566, IRB@iastate.edu, or Director, (515) 294-3115, Office of Research Assurances, Iowa State University, Ames, Iowa 50011.

PARTICIPANT SIGNATURE
Your signature indicates that you voluntarily agree to participate in this study, that the study has been explained to you, that you have been given the time to read the document and that your questions have been satisfactorily answered. You will receive a copy of the written informed consent prior to your participation in the study.

Participant’s Name (printed)

(Participant’s Signature)   (Date)
INVESTIGATOR STATEMENT

I certify that the participant has been given adequate time to read and learn about the study and all of their questions have been answered. It is my opinion that the participant understands the purpose, risks, benefits and the procedures that will be followed in this study and has voluntarily agreed to participate.

_________________________  __________________________
(Signature of Person Obtaining Informed Consent)  (Date)
APPENDIX C. PRETEST/POSTTEST DATA COLLECTION FORM

INSTRUCTIONS AND DATA SHEET
For Older Adult Balance Training Study

Name __________________________ Birthdate __________ Study ID _____

Today’s Date _________________ Trial: Pre Post

How are you feeling today? Excellent Good Fair Poor

HEIGHT: __________

WEIGHT: __________

Please check off each item as it is completed.

____ FORCE PLATFORM

EXAMINER’S INITIALS _____ _____

Computer:
Open My Computer→Drive C→AMTI-NetForce→Balance Training
FILE→New→Folder
Name the folder ID#Post
Minimize My Computer

Open AMTI-NetForce
Select SUBJECT
Click on Query and enter ID#
Double click on the subject and update the date. Change the comment to post test.
Click Update
Click Select
Make sure Balance Training.pro is listed under protocol name and the subject’s name is listed.

Computer: Press START, TARE, ARM before subject steps onto platform. After subject has received instructions, hit spacebar to start each trial. A time bar will move across the top of the screen. At the end of 30 seconds, say “OK”. Examiner will ask subject to step back onto wood block. Then start, tare, arm for the next trial. THIS SEQUENCE IS REPEATED FOR EVERY TRIAL. Two measures will be taken in each condition. Select NEXT when ready to move to the next condition.

DO NOT HIT ‘STOP’ AT ANY TIME DURING DATA COLLECTION.
Examiner: Ask the participant to remove shoes, but keep socks on. Have them step on the platform with center of foot over horizontal tape line, placing each foot on either side of the vertical tape line. Make sure feet are touching and heels and toes are even with one another. Tape along the outside of the toes and heels and at a diagonal from the toes to the outer edge of the foot. The participant will stand within these tapelines for each trial. When conducting trials on foam, place the same tape lines on the foam before measuring begins.

**Balance Conditions**

**Eyes Open:** *Stand as quietly as possible, arms across your chest (like this--demonstrate), eyes focused on the black circle.*

Save PT, ID#, subject initials EO1__________ (all trials saved as BT, ID# for pretest records)
Save PT, ID#, subject initials EO2__________
hit NEXT

**Eyes Closed:** *Stand as quietly as possible, arms across your chest with eyes focused on the black circle. Then I will say “close”. Close your eyes and keep them closed until I say “open”.*

Save PT, ID#, subject initials EC1__________
Save PT, ID#, subject initials EC2__________
hit NEXT

**Leaning:** *First I will demonstrate, and then you will practice once before we record. Stand on the platform with feet together, arms across your chest, eyes focused on the black circle. Keep your legs straight without locking the knees. When I say ‘forward’, shift your weight forward as far as quickly as possible and hold that position while keeping both feet on the platform and the body and legs straight like a board. Try not to bend anywhere except at the ankle. When I say ‘center’, return your weight to the center of the platform. When I say ‘back’, shift your weight backward as quickly as possible and hold until I say ‘center’, then return to the center of the platform. When I say ‘right’, shift your weight right as quickly as possible and hold, making sure that both feet continue to touch the platform, keeping the body straight. Return to center and when I say ‘left’, shift your weight as quickly as possible to the left and hold. On cue, return to center and stand quietly until I ask you to step back. My assistant will stand behind you during the practice and test.*

Save PT, ID#, Subject initials L1__________
Save PT, ID#, Subject initials L2__________

After hitting spacebar, step behind the subject to spot during the test.

hit NEXT
Single Leg Left: We would now like you to stand on one leg. We will begin by standing on the left leg. I’ll say “whenever you are ready lift the right foot”. Pick up your right foot so that the toes are even with the ankle of the standing leg keeping your hands crossed over your chest and your eyes focused on the black circle. Don’t touch or brace your foot on your other leg. If you feel like you are going to lose your balance or fall, then put your foot down. We will time how long you can continue to stand on one leg without putting your foot down. Once you put your foot down, step off the platform.

Save PT, ID#, Subject initials_SLL1_________ TIME IN SEC_________
Save PT, ID#, Subject initials_SLL2_________ TIME IN SEC_________

Computer operator will use the stopwatch to time single-leg-stance up to 45 seconds. Hit spacebar and stopwatch at the same time. Stop the stopwatch whenever the subject touches his/her foot down. The computer will continue to run for 30 seconds. The first time will be used in the Berg Balance Scale.
Hit NEXT

Single Leg Right: Now we will stand on the right leg. I’ll say “whenever you are ready lift the left foot”. Pick up your left foot so that the toes are even with the ankle of the standing leg keeping your hands crossed over your chest and your eyes focused on the black circle. Don’t touch or brace your foot on your other leg. If you feel like you are going to lose your balance or fall, then put your foot down. We will time how long you can continue to stand on one leg without putting your foot down. Once you put your foot down, step off the platform.

Save PT, ID#, Subject initials_SLR1_________ TIME IN SEC_________
Save PT, ID#, Subject initials_SLR2_________ TIME IN SEC_________
Hit NEXT

Tandem: We will first practice this stance on the floor. Demonstrate. Place one foot directly in front of the other on the diagonal tapeline, so that you are standing heel to toe. The heel and toe should be centered where the tape intersects at the middle of the platform. Keep the eyes focused on the red light on the boom box in front of you. We will time how long you can remain in this position without taking a step. My assistant and I will stand close to you to spot you. (Assist subject into the position if needed).

Save PT, ID#, Subject initials_T1_____________ TIME IN SEC _________
Save PT, ID#, Subject initials_T2_____________ TIME IN SEC _________

Computer operator will use the stopwatch to time tandem stance. Hit spacebar and stopwatch at the same time. Stop the stopwatch whenever the subject takes a step or reaches for assistance. IF THE SUBJECT CAN ASSUME THE POSITION WITHOUT ASSISTANCE, ALLOW THE TIMER TO RUN UP TO 45 SECONDS AND RECORD THE TIME ON THE BERG BALANCE SCALE.
hit NEXT
Foam Eyes Open: Place the foam on the platform BEFORE start, tare, arm. Ask the subject to line their feet up with the cross just as they did on the force platform and tape around the feet. *Stand as quietly as possible, arms across your chest eyes focused on the black circle.*

Save PT, ID#, Subject initials_FOAM-EYES-OPENED1__________
Save PT, ID#, Subject initials_FOAM-EYES-OPENED2__________
hit NEXT

Foam Eyes Closed: *Stand as quietly as possible, arms across your chest with eyes focused on the black circle. Then I will say “close”. Close your eyes and keep them closed until I say “open”.*

Save PT, ID#, Subject initials_FOAM-EYES-CLOSED1__________
Save PT, ID#, Subject initials_FOAM-EYES-CLOSED2__________
hit NEXT

Computer: At the completion of the trials, find all of the client files in My Computer under AMTI-NetForce. Select all the client files—there should be 16—COPY and PASTE them to their folder in the Balance Training Folder.

Add a new folder for the next subject.

<table>
<thead>
<tr>
<th>ACTIVITIES-SPECIFIC BALANCE CONFIDENCE SCALE</th>
</tr>
</thead>
</table>

Record Participant Name, ID #, write ‘pre’ under group, and date on the ABC. Read the instructions for the ABC to the participant and ask if they have any questions. Allow them to complete the form.

AFTER THEY HAVE COMPLETED ABC, PLEASE ASK THE FOLLOWING QUESTIONS AND RECORD THE ANSWER HERE.

PRETEST QUESTIONS:
How would you rate your eyesight (with glasses or contacts)?  Excellent  Good  Fair  Poor

How many times have you fallen in the last year?  None  Once  2 or 3 times  More than 3 times
POSTTEST QUESTIONS: Show the participant the activity portion of their medical history and ask the following questions:
Please look at your activity history.
Are you still currently participating in the activities listed here? YES  NO
(Please make sure specific activities are listed, such as weight lifting vs. cardiovascular, including duration and frequency)
If not, tell me about the changes (what have you added or dropped).

___________________________________________________________________________
___________________________________________________________________________
___________________________________________________________________________

“I will be asking you to perform several different tasks. Please maintain your balance while completing the tasks.” Read the instructions as printed.

REACHING FORWARD WITH OUTSTRETCHED ARM WHILE STANDING
INSTRUCTIONS: Place your feet in a comfortable standing position. Lift arm to shoulder height. (Examiner tapes a ruler to the wall at subject’s shoulder height while arm is at 90 degrees). Use a clipboard to identify the point on the ruler where the subject’s middle finger reaches. Stretch out your fingers and reach forward as far as you can without touching the wall, keeping the arms parallel to the ruler. Make sure you keep both heels on the floor and use both arms when reaching. The recorded measure is the distance forward that the fingers reach while the subject is in the most forward leaning position. Use the clipboard to measure the ending point, and then subtract the starting point to find the total length reached. Record in centimeters. PLEASE COMPLETE THREE TRIALS.

Record forward reach in cm____  _____  _____
(    ) 4  can reach forward confidently 25 cm (10 inches)
(    ) 3  can reach forward 12 cm (5 inches)
(    ) 2  can reach forward 5 cm (2 inches)
(    ) 1  reaches forward but needs supervision
(    ) 0  loses balance while trying/requires external support

PICK UP OBJECT FROM THE FLOOR FROM A STANDING POSITION
INSTRUCTIONS: Place a pen 5 inches in front of the subject’s feet. Please pick up the pen, which is placed in front of your feet. Choose whatever method is most comfortable for you.
(    ) 4  able to pick up pen safely and easily
(    ) 3  able to pick up pen but needs supervision
(    ) 2  unable to pick up but reaches 2-5 cm (1-2 inches) from pen and keeps balance independently
(    ) 1  unable to pick up and needs supervision while trying
(    ) 0  unable to try/needs assist to keep from losing balance or falling
TURNING TO LOOK BEHIND OVER LEFT AND RIGHT SHOULDERS WHILE STANDING
Omit this measure if the subject has diagnosed osteoporosis of the spine.
INSTRUCTIONS: Without taking a step, turn safely to look directly behind you over toward the left shoulder. Take your time. Repeat to the right.
( ) 4 looks behind from both sides and weight shifts well
( ) 3 looks behind one side only other side shows less weight shift
( ) 2 turns sideways only but maintains balance
( ) 1 needs supervision when turning
( ) 0 needs assist to keep from losing balance or falling

TURN 360 DEGREES
INSTRUCTIONS: Have the subject face you. Begin by facing me. Turn completely around in a full circle until you face me again. Time the turn with the stopwatch. Start the timer when you say “begin”. Stop the timer when the subject is facing you again. Record the time. Now turn a full circle in the other direction. Time the turn & record. TWO TRIALS IN EACH DIRECTION.
First turn time in seconds______ _______
Second turn time in seconds______ _______
( ) 4 able to turn 360 degrees safely in 4 seconds or less
( ) 3 able to turn 360 degrees safely one side only 4 seconds or less
( ) 2 able to turn 360 degrees safely but slowly
( ) 1 needs close supervision or verbal cuing
( ) 0 needs assistance while turning

PLACE ALTERNATE FOOT ON STEP OR STOOL WHILE STANDING UNSUPPORTED
INSTRUCTIONS: Brace the stool against the wall. Place each foot alternately on the step/stool. Make sure you place the whole foot on the stool. (Demonstrate) Please move as quickly and safely as you can until I tell you to stop. Ready, begin. Record time to complete 8 steps from the time you say ‘begin’ until the foot has been placed fully on the floor after the 8th step. RECORD TWO TRIALS.
Time in Seconds______ _______
( ) 4 able to stand independently and safely and complete 8 steps in 20 seconds
( ) 3 able to stand independently and complete 8 steps in > 20 seconds
( ) 2 able to complete 4 steps without aid with supervision
( ) 1 able to complete > 2 steps needs minimal assist
( ) 0 needs assistance to keep from falling/unable to try
STANDING UNSUPPORTED ONE FOOT IN FRONT
INSTRUCTIONS: (DEMONSTRATE TO SUBJECT) Place one foot directly in front of the other. If you feel that you cannot place your foot directly in front, try to step far enough ahead that the heel of your forward foot is ahead of the toes of the other foot. (To score 4 points the subject must be able to assume the position without assistance. To score 3 points, the length of the step should exceed the length of the other foot and the width of the stance should approximate the subject’s normal stride width.) Time the subject for a maximum of 45 seconds. Stop the timer when the person steps out of the stance.

Time in seconds _______________
( ) 4  able to place foot tandem independently and hold 30 seconds
( ) 3  able to place foot ahead independently and hold 30 seconds
( ) 2  able to take small step independently and hold 30 seconds
( ) 1  needs help to step but can hold 15 seconds
( ) 0  loses balance while stepping or standing

STANDING ON ONE LEG THIS ITEM WILL BE SCORED ON THE FORCE PLATFORM

( ) 4  able to lift leg independently and hold > 10 seconds
( ) 3  able to lift leg independently and hold 5-10 seconds
( ) 2  able to lift leg independently and hold ≥ 3 seconds
( ) 1  tries to lift leg unable to hold 3 seconds but remains standing independently.
( ) 0  unable to try of needs assist to prevent fall

<table>
<thead>
<tr>
<th>GAIT ANALYSIS</th>
<th>EXAMINER’S INITIALS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Computer: Open GaitRite on the desktop
Triple click to enter

Select NEW SUBJECT→YES
Enter participant initials under first name
Enter PT followed by ID number under last name (example: BT999)
Enter birthdate and gender
(If participant is taller than 6’4”, please enter leg length)
SAVE
Select NEW TEST
Select MEMO
Label the condition ‘PF’ for preferred or ‘F’ for fast pace (enter label in both boxes)
SAVE/BACK
Select START WALK
When screen says “begin walking”, follow script below.
When walk is complete, hit DONE→SUSPEND WALK FOR LATER PROCESSING
Repeat process from ‘Memo’ above using PF2 for trial 2 and PF 3 for trail 3.
Preferred Pace: “This test will measure how you walk. Please walk from the first blue tape line to the blue tape line at the other side of the mat. Please walk straight down the mat to the right of the gray boxes. For our first three trials, please walk at your preferred pace, the pace you might use if you were walking leisurely. This should be a comfortable pace for you. Ready, begin.”

PF __________
PF 2__________
PF3 __________

Fast Pace: “For our next three trials, please walk at a FAST pace. Walk as quickly as you can from one tapeline to the next. Ready, begin.”

F __________
F2 __________
F3 __________

Computer: After final trial select EXIT
Click the Man/Woman icon
Click on the row that says NEW SUBJECT
Repeat the directions above for the next subject.
APPENDIX D. MEDICAL HISTORY FORM
THE EXERCISE CLINIC AT ISU – MEDICAL HISTORY

Today’s Date: _____/_____/_____

______________________________

Personal Information

Name: _______________________ Age: _____ Date of Birth: ___/___/___ Sex: _____
Address: ___________________________________ Telephone No: ____________________
Employer: _________________________ e-mail address: ____________________________

______________________________

Emergency Information

Personal Physician’s
Physician: __________________________________________ Telephone No: _________
Physician’s Address: __________________________________________________________

Individual to be contacted in case of an emergency: ___________________________________
Relationship to you: _______________________________
Home Address: ______________________________ Home Telephone No: _______________
Work Address: ______________________________ Work Telephone No: _______________

______________________________

Do you have medical alert identification? _______ YES _______NO
If YES, where is it located? ________________________________

______________________________

Current Medications (include ALL medications)

<table>
<thead>
<tr>
<th>Name of Drug</th>
<th>Dosage; Times/day</th>
<th>Why are you on this drug?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
</tbody>
</table>
Personal Medical History

Do you have any known allergies? ______ YES ______NO
If YES, please explain: _____________________________________________________________

Do you use tobacco products? ___YES ___NO   If YES, please describe product used (cigarettes, pipe, dip, etc.), how often per day (packs, bowls) and how long you have been a tobacco user (yrs):
____________________________________________________________________________

What is your cholesterol level? ____________ mg/dl ____________don’t know
What is your resting blood pressure? ______________ mm Hg ___________ don’t know

Please check the following disease conditions that you had or currently have:

____ High blood pressure       ____ Aneurysm       ____ Abnormal chest X-ray
____ High blood cholesterol    ____ Anemia         ____ Asthma
____ High blood triglycerides  ____ Diabetes       ____ Emphysema
____ Angina pectoris           ____ Jaundice       ____ Bronchitis
____ Heart attack              ____ Hepatitis      ____ Thyroid problems
____ Heart surgery (catheter, bypass) ____ Infectious mono ___ Hernia
____ Heart failure             ____ Phlebitis      ____ Cancer
____ Heart murmur              ____ Gout           ____ Epilepsy or seizures
____ Stroke/transient ischemia attacks ___ Kidney stones ___ Prostate problem
____ Rheumatic fever           ____ Urinary tract infections ___ Osteoporosis
____ Arteriosclerosis          ____ Emotional disorder ___ Eating disorder

Please provide dates and explanation to any of the above which you checked: ________________
________________________________________________________________________________

Have you experienced, or do you currently experience any of the following on a recurring basis?

At rest: YES NO During exertion: YESNO

Shortness of breath
Dizziness, lightheadedness, fainting
Daily coughing
Discomfort in the chest, jaw, neck or arms (pressure, pain, heaviness, burning, numbness)
Skipped heart beats or palpitations
Rapid heart rate
Joint soreness
Joint swelling
Slurring or loss of speech
Unusually nervous or anxious
Sudden numbness or tingling
Loss of feeling in an extremity
Blurring of vision

If YES to any of the above, please explain:

________________________________________________________________________________
**Hospitalizations**

Please list the last three (3) times you have been ill (sick) enough to see a physician, been hospitalized or had surgery.

<table>
<thead>
<tr>
<th>When?</th>
<th>What was done (surgery, etc.)?</th>
<th>Why was this done?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
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</tbody>
</table>

**Family History**

Have any members of your immediate family had, or currently have, any of the following?

<table>
<thead>
<tr>
<th>Heart Disease</th>
<th>Stroke</th>
<th>Diabetes</th>
<th>Sudden Death</th>
<th>Pulmonary Disease</th>
<th>Age of onset</th>
</tr>
</thead>
<tbody>
<tr>
<td>Father</td>
<td>______</td>
<td>______</td>
<td>______</td>
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<td>Aunts/Uncles</td>
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**Orthopedic/Musculoskeletal Injuries**

Please check the following disease or conditions which you had or currently have:

- ____ Arthritis
- ____ Swollen joints
- ____ Painful feet
- ____ Severe muscle strain
- ____ Limited range of motion in any joint
- ____ Bursitis
- ____ Osteoporosis
- ____ Muscle weakness
- ____ Stiff or painful muscles
- ____ Fractures or dislocations
- ____ Tennis elbow
- ____ Torn ligaments
- ____ Pinched nerve
- ____ “Trick” knee/knee injury
- ____ Head injury
- ____ Shoulder injury
- ____ Ankle injury
- ____ Whiplash or neck injury
- ____ Slipped disc
- ____ curvature of spine

Do any of the above limit your ability to exercise? _____ YES _____ NO  If YES to any of the above, please explain: _____________________________________________________________________
Activity History

Please list any physical or recreational activities that you currently do or have done on a regular basis.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Frequency (days/week)</th>
<th>Time (min/session)</th>
<th>How long (years)</th>
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Diet History

What do you consider a “good” weight for you? _____ Lbs. When did you weigh this? ______
What is the most you have ever weighed? _____ Lbs. When did you weigh this? ______
In the past 5 years, how often have you attempted to lose weight? ______
What diets did you use? _____________________________________________________________
________________________________________________________________________________
How many meals do you usually eat per day? _____________
How many cups of coffee or caffeinated beverages do you drink per day? ______________
How many servings (1 shot, glass of wine, 12 oz of beer) do you drink per week? ______________
On average, how often do you eat the following foods per week?

_____ cheeses (cheddar, American, etc.) _____ eggs (alone or in foods) _____ poultry
_____ fast foods (McDonalds, etc.) _____ fried foods (non fast foods) _____ non diet pop
_____ beef, pork, veal or lamb _____ shellfish or organ meats (liver, giblets, etc.)

Vocational History

What is your present occupation? _______________________________________________________
Years at present occupation? _________________________________________________________
Hours worked per day: __________ Days per week: ___________ Shift: __________________
How would you perceive the average physical demands of your job (check one):

_____ light   _____ fairly light   _____ somewhat hard   _____ hard   _____ very hard
Briefly describe what your job involves: _______________________________________________
________________________________________________________________________________
Approximately what percentage of your day is spent:

_____ sitting      _____ standing      _____ walking      _____ carrying objects      _____ lifting objects

Please describe any objects you must lift and/or carry at your job:

_________________________________________________________________________________

_________________________________________________________________________________

How many hours of your work day are spent: _____ indoors      _____ outdoors

Are you exposed to excessive heat, cold, air pollution, or other environmental hazards at your job?

_____YES      _____ NO  If YES, please describe:

_________________________________________________________________________________

_________________________________________________________________________________

How would you perceive the average *psychological demands* or *stressfulness* of your job?

*Severity* of stress:

_____ none      _____ fairly light      _____ moderate      _____ severe      _____ very severe

*Frequency* of stress:

_____ almost never      _____ occasionally      _____ frequently      _____ very frequently      _____ constantly