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The Effect of Exercise Ball Training on Balance in Older Adults

Stephanie Happ

Eastern Illinois University

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The Effect of Exercise Ball Training
on Balance in Older Adults

(TITLE)

BY

Stephanie Happ

THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

Master of Science in Physical Education

IN THE GRADUATE SCHOOL, EASTERN ILLINOIS UNIVERSITY
CHARLESTON, ILLINOIS

2002

YEAR

I HEREBY RECOMMEND THAT THIS THESIS BE ACCEPTED AS FULFILLING
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ABSTRACT

Prevention of falls through balance training is of great interest to the aging population. Falls can cause debilitating injuries, such as fractures, and can also lead to the beginning of a series of health complications. These resulting complications can cause the older individual to become feeble, and susceptible to future recurring falls. There is no previous research on the effects of Swiss Ball exercises on the balance of older adults. The purpose of this study was to evaluate the efficacy of an exercise regimen involving the use of Swiss Balls to improve the balance of older adults.

Eleven apparently healthy subjects over the age of sixty who had no history of falls volunteered to participate in this study. Six subjects participated in the exercise group, which involved supervised participation in a Swiss Ball exercise program for a period of 10 weeks. Five subjects participated in the control group, which did not perform any form of exercise that was new to them during the 10-week training period. Balance testing of all subjects was conducted before and after the 10-week training period. This testing included one-legged stance tests, tandem (heel-to-toe) stance tests, tandem (heel-to-toe) walking tests, a 30-meter timed walk, and 30-second chair stand test. Nine subjects completed the study. A MANOVA test was performed to determine any differences in change scores between the two groups.

The results of the MANOVA test indicated that there was a significant difference between the change scores of the exercise and control groups for the 30-meter timed walk and the chair stand tests (p = .010 and .004 respectively.)
The expectation of this study was to find a significant difference in change scores between the exercise and control groups. The exercise ball training was intended to improve the function of the muscles that regulate posture and upright stance, and therefore improve the balance of the subjects who participated in the ball exercises. Although the results of this study did not reveal any significant changes in the balance of either group, a significant improvement in walking speed and the number of chair stands performed within 30 seconds was found in the exercise group after the training period. Because leg strength and walking speed are two factors that predict balance test scores, improvements in balance should have been expected. Some small improvements were found in the balance test scores of the exercise group after the training period, although the improvements were insignificant. This may be due in part to low power as the subject number in this study was small. Also, if the length of the training period had been longer, the results may have been more significant. Further study is warranted with larger population samples in order to determine if exercise ball training is an effective mode of improving balance.
I would like to acknowledge all of those who have been instrumental in the completion of this project. Without all of you I would have never attempted to accomplish this feat.

Special thanks in due to my committee, Dr. Phyllis Croisant, Dr. Jake Emmett, and Dr. Jill Owen, all of whom were very enthusiastic and insightful while helping me with this study. I would like to especially recognize Phyllis Croisant for sparking my interest in doing my own research and for helping me realize all that I could accomplish.

I cannot pass the opportunity to also recognize all of my family and friends; without their love and support I would never have made it this far. They have always had an ability to make me see the humor and rationale in every situation and helped me to believe in myself whenever I may have been in doubt. I love you all very much. I especially would like to thank my parents who have helped me in every way throughout my scholastic endeavors. I am lucky to have had this opportunity.
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Loss of balance is a common characteristic among the aging population. Postural and gait changes that occur due to the aging process are so easily recognizable, that they can be imitated by most individuals. These changes include stooped shoulders, lack of trunk and back flexibility, slow, small steps, and carefully monitored movements. Postural changes and loss of balance occur for a number of reasons, including loss of strength in the muscles that provide postural control and movement, changes in joint and bone structure, loss of vestibular function, and decreased somatosensory proprioception.

Unfortunately, loss of balance contributes to falls in the elderly. About 30 percent of all adults over the age of 65 living at home will fall each year (Tibbits, 1996). The consequences of these falls can be severe. A fracture may be only the beginning of a series of resulting complications, including soft tissue injury, increased risk of future fractures, and pneumonia. Many fractures, such as those at the hip, leave an elderly individual immobilized for long periods of time. The health of the individual begins to decline rapidly as he or she becomes increasingly dependant on others for daily tasks. When these individuals rely on others to perform daily tasks, their ability to perform daily tasks on their own diminishes. Falls are often the beginning of a downward spiral of health problems for the elderly. Even if no serious injury has occurred in an individual who has fallen, a decline in self-confidence often causes him or her to avoid physical activity or social situations in order to avoid additional falls. This decline in physical activity and social interaction puts the individual at an increased risk for future falls.
It has been established that exercise helps to improve balance and prevent falls in seniors. However, some studies do not demonstrate improved balance in seniors as a result of training. Various studies have been published in which different modes of exercise have been shown to increase scores on balance tests. These modes of exercise have included aerobic endurance training, strength training, balance training, or various combinations of these modes. It is most likely that if balance test scores were improved following such exercise training regimens, then the subjects’ risk of falling would be reduced.

Exercise balls, also known as Swiss balls, physioballs, or body balls, have been used for years in physical therapy settings. Recently, exercise balls have been introduced into the fitness industry as a mode of training for various purposes. One of these purposes is increasing “core stability” and balance. One should assume that “core stability” refers to the synergistic contraction of the muscles of the abdomen and lower back. In addition, exercise balls can be used to strengthen other muscles, including those of the legs.

Purpose of the Study

The purpose of this study was to determine if an exercise ball training regimen could be used to improve the balance of older adults. Six adults, aged 65 to 76, trained two days a week for approximately fifteen minutes each day for a period of ten weeks at the Senior Center in Charleston, Illinois. Training involved sitting on exercise balls and shifting of body weight in order to perform various exercises. In addition, strengthening
exercises for the thighs and lower legs were performed while utilizing the balls. Static and dynamic balance testing, and a chair stand test were performed before and after the training period. These tests were intended to identify any changes in balance, gait speed, or leg strength that may have occurred as a result of the exercise ball training. In addition, a control group, which did not participate in the exercise ball training, also performed the balance tests before and after the training period in order to provide a means of comparison for the training group.

Hypothesis

The primary hypothesis of this study was that exercise ball training would result in improved balance scores of participants. This was expected to occur as a result of several adaptations to the training. These adaptations included improved postural stability; increased speed of recovery reactions, increased leg strength, and improved use of the proprioceptive senses for postural adjustments needed for balance. If one or more of these adaptations had occurred, the balance test scores of the exercise group should be improved after the training period more so than the control group’s balance test scores after the same ten-week period. In addition to improvements in balance test scores, improvements in leg strength and in walking speed, as indicated by chair stands and the 30-meter walk, were expected to be greater in the exercise group, compared to the control group.
Limitations of the Study

Because of a lack of individuals who were willing to commit themselves to a ten-week training period, there were a small number of volunteers for this project. In addition, the exercise balls may have intimidated other individuals, as all subjects were unfamiliar with this form of exercise. Therefore the subject sample was smaller than initially intended.

In addition to small sample size, all subjects were volunteers. These individuals may have been different than the average population because of an increased interest in physical well-being or in balance. They also may have been more receptive to trying new activities or may have been more socially oriented than individuals who did not volunteer to participate in this study.

The length of this study may have also been insufficient to produce significant changes in testing scores. Ten weeks was chosen in order to encourage more volunteers for this research, but more training adaptations may have occurred if the training was continued for a longer time period.

Definitions of Terms

Dynamic Balance- balance required in maintaining the body's center of mass over its base of support during movements such as reaching or walking.
Fallers- Individuals who have not fallen or who have fallen less than two times within one year.

Labile Surface- movable surface, such as foam, wobble boards, or Swiss balls, often used for balance training purposes.

Limits of Stability- the range in which the body’s center of mass may move over its base of support without the occurrence of loss of balance.

Non-Fallers- individuals who have fallen two or more times within one year.

Postural Sway- minor shifts in body weight and alignment that increase with age.

Posture- the alignment of body parts in relation to one another. Ideal posture conserves muscular energy (Kauffman, 1990).

Static Balance- balance required in maintaining the body’s center of mass over its base of support during quiet standing.
Balance in Older Adults

Changes in Posture and Alignment

Postural changes occur in most adults over the age of 60. These changes often include a head-forward position, rounded shoulders, dorsal kyphosis, and flattening of the lumbar spine. An increased growth of connective tissue in the muscles often causes flexibility to deteriorate and causes weakness in the muscles that are constantly stretched. Stretch weakness is common in the scapular retractors and the trunk extensors. Spinal degradation occurs due to narrowing disk space, osteophytes, and sclerosis of vertebral endplates. Leg length may also be altered due to wear or injury of the joints, or due to joint replacements. Pain or swelling of muscles and/or joints also causes individuals to alter their posture. Therefore, the functional ability of each older individual varies widely (Kauffman, 1990).

During normal quiet posture, every individual has some degree of postural sway, or movement of his or her center of mass over its base of support. This postural sway is often greater in fallers than in non-fallers. Individuals who had a fear of falling were found to have more spontaneous postural sway, as determined by force plates during both blindfolded and eyes-open one-legged stance tests. However, fear of falling in this particular study may have stemmed from declining postural control. Although it is difficult to determine which occurred first, it is widely known that individuals who have a
TETANUS AND DIPHTHERIA VACCINE (Td)

What you need to know before you or your child gets the vaccine

ABOUT THE DISEASES

Tetanus (lockjaw) and diphtheria are serious diseases. Tetanus is caused by a germ that enters the body through a cut or wound. Diphtheria spreads when germs pass from an infected person to the nose or throat of others.

<table>
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<th>Tetanus causes: serious, painful spasms of all muscles</th>
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<td>It can lead to: - &quot;locking&quot; of the jaw so the patient cannot open his or her mouth or swallow</td>
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ABOUT THE VACCINES

Benefits of the vaccines

Vaccination is the best way to protect against tetanus and diphtheria. Because of vaccination, there are many fewer cases of these diseases. Cases are rare in children because most get DTP (Diphtheria, Tetanus, and Pertussis), DTaP (Diphtheria, Tetanus, and acellular Pertussis), or DT (Diphtheria and Tetanus) vaccines. There would be many more cases if we stopped vaccinating people.

When should you get Td vaccine?

Td is made for people 7 years of age and older.

People who have not gotten at least 3 doses of any tetanus and diphtheria vaccine (DTP, DTaP, or DT) during their lifetime should do so using Td. After a person gets the third dose, a Td dose is needed every 10 years all through life.

Other vaccines may be given at the same time as Td.

Tell your doctor or nurse if the person getting the vaccine:

- ever had a serious allergic reaction or other problem with Td, or any other tetanus and diphtheria vaccine (DTP, DTaP, or DT)
- now has a moderate or severe illness
- is pregnant

If you are not sure, ask your doctor or nurse.

What are the risks from Td vaccine?

As with any medicine, there are very small risks that serious problems, even death, could occur after getting a vaccine.

The risks from the vaccine are much smaller than the risks from the diseases if people stopped using vaccine.

Almost all people who get Td have no problems from it.
Mild problems

If these problems occur, they usually start within hours to a day or two after vaccination. They may last 1-2 days:
- soreness, redness, or swelling where the shot was given

These problems can be worse in adults who get Td vaccine very often.

Acetaminophen or ibuprofen (non-aspirin) may be used to reduce soreness.

Severe problems

These problems happen very rarely:
- serious allergic reaction
- deep, aching pain and muscle wasting in upper arm(s). This starts 2 days to 4 weeks after the shot, and may last many months.

What to do if there is a serious reaction:

1. Call a doctor or get the person to a doctor right away.
2. Write down what happened and the date and time it happened.
3. Ask your doctor, nurse, or health department to file a Vaccine Adverse Event Report form or call:
   (800) 822-7967 (toll-free)

The National Vaccine Injury Compensation Program gives compensation (payment) for persons thought to be injured by vaccines. For details call:
   (800) 338-2382 (toll-free)

If you want to learn more, ask your doctor or nurse. She/he can give you the vaccine package insert or suggest other sources of information.
fear of falling often display an abnormal posture and gait due to reactive mechanisms. These individuals appear to have a rigid posture, hold their arms out to their sides, and take smaller and wider steps (Maki, Holliday, and Topper, 1991).

Regulation of upright stance requires a coordinated effort of both agonist and antagonist muscles for every movement. For example, in a study where younger subjects (under age 60) pulled on a handle in response to a light signal, the subjects adjusted their posture just before pulling the handle by activating their gastrocnemius, biceps femoris, and erector spinae, respectively, in order to compensate for the forward displacement of their bodies that would result from pulling on the handle (Frank and Earl, 1990). Similar adjustments must occur before the initiation of any movement in order to maintain the body’s center of mass over its base of support.

An electromyographical study by Hodges, Richardson, and Hasan (1997) found that muscles of the abdomen contracted before muscles of the hip during hip flexion, extension, and abduction in the standing position among healthy subjects aged 18 to 25 years. It was observed that the trunk muscles contracted in an inward to outward fashion beginning with the transverse abdominus and multifidus, followed by the internal obliques, external obliques, and rectus abdominus, respectively. These were active before movement of the limbs in order to stabilize the trunk in preparation for movement of its center of mass. Fine electrodes placed in the left transverse abdominus, left internal oblique, left external oblique, and left posterior gluteus medius indicated that during each movement, initiation of transverse abdominus contraction occurred 35 to 104 milliseconds before contraction of other muscles was initiated. In addition, the internal obliques, and multifidus muscles all contracted prior to the contraction onset of the
primary mover. Anticipatory postural adjustments involving the trunk region ensure that the spine remains stable and upright during gait and righting reactions.

While most biomechanical models have focused on the ankle and hip strategies for postural control, a computerized dynamic posturography system has been used to develop a model for head and trunk coordination strategies as well. The head-trunk strategies may be helpful in maintaining visual and vestibular sensory inputs (Nicholas, Doxey-Gasway, and Paloski, 1998).

In summary, postural changes and increased postural sway cause a decrease in the control of posture and of balance. Postural adjustments of the trunk and limbs are necessary before any movement in order to maintain balance, however these adjustments may be delayed in older individuals.

Gait and Dynamic Balance

During ambulation, gravity acts upon the body as the leg moves forward. A counterbalancing action must occur about the hip and lower trunk in order to prevent the body from falling forward and in order to aid weight shift to the opposite leg. Hip flexion keeps the body from falling forward, while hip extension keeps the body from falling backward. Because approximately two-thirds of the body's weight is located in the upper portion, stabilization of the torso over the legs is highly important (Woollacott and Tang, 1997).

In addition to anterior and posterior motion control, the torso must also be controlled laterally. The hip abductors, lateral trunk flexors, and the ankle invertors and evertors provide lateral stability during gait. The hip abductors control step width. Older
adults generally have a more variable step width than do younger adults (Woollacott and Tang, 1997). Taking wider steps increases the body’s base of support and therefore is a protective mechanism for maintaining an upright position during walking or at rest.

Walking speed and measures of gait variability were found to be similar in non-falling elderly over the age of 70 years and young subjects with an average age of 25 years. Elderly subjects who were classified as fallers in the same study were found to have significantly greater gait variability compared to both the young subjects and the elderly non-fallers (Hausdorff, Edelberg, Mitchell, Goldberger, and Wei, 1997). In another study, stride length and walking speed of fallers was found to be only 65% and 55% respectively of non-fallers (Wolfson, Judge, Whipple, and King, 1995).

Proprioception and Somatosensory Input

Proprioceptive and somatosensory inputs assist in postural control and volitional movement and are used more so than vestibular and visual inputs during quiet stance. Proprioceptive senses are used mostly for simple tasks, but are also important during more complex, learned movements and recovery of balance. The corticospinal tract, or pyramidal system, is responsible for major postural adjustments (Shepard and Solomon, 2000).

One of the proprioceptive mechanisms is the myotic reflex, more commonly known as the stretch reflex. Although no coordinated movements are produced, joint stability is maintained when an external pull on a muscle stimulates an inner muscle spindle, causing the muscle to contract. The spine mediates this response. A second mechanism, the functional stretch response, is stimulated via somatosensory input and is
mediated through the spine, brain stem, and basal ganglia to produce coordinated arm, leg, and trunk movements, in order to recover from postural disturbances. Volitional movements, which are more complex, learned movements than reflexes, require proprioceptive and somatosensory responses as a foundation of postural control. Volitional movements are regulated by the cortical sensory and motor areas of the brain (Shepard and Solomon, 2000).

Lassau-Wray and Parker (1993) used electromyography to demonstrate delays in neuromuscular response when pressing a hand-held button in response to a light stimulus in non-falling women aged 65 to 75 years compared to women aged 19 to 30 years. This finding was more pronounced during walking than during standing. The delay of reaction increased as the complexity of the walking increased. This may have occurred because the older subjects had a delay of central thought processing during more complex tasks due to decreased ability to control balance.

Woollacott and Shumway-Cook (1990) proposed that older adults might have a deterioration of higher-level neural control mechanisms, which may cause primitive control systems to reemerge after being suppressed since childhood. These lower-level reflexes may confine the higher-level equilibrium reactions. This results in delays in the organization of postural muscle responses to balance disturbances. Decreased sensory input (visual, somatosensory, or vestibular) or inconsistent sensory inputs contribute to delays in neuromuscular responses.
Vestibular Function

The inner ear consists of a series of canals. The three semicircular canals are arranged at right angles to each other and contain fluid ducts with receptor cells that detect head movement. Also located in the inner ear is the vestibule, which consists of spherical compartments that detect positioning and movement of the head. The number of sensory cell within the vestibular organs begins to decline by age 50. This decline is especially noticeable after age 70. In addition, the neurons in the cerebellum that receive equilibrium sensory information also are lost with age (Spence, 1995).

The function of the vestibular system is to sense an orientation of the body in space in relation to gravity and movement. It helps in maintaining a clear visual image of the world while the head is in motion or while surrounding objects are in motion, and it helps in maintaining upright stance during static and dynamic balance (Shepard and Solomon, 2000).

The vestibulo-ocular reflex is a compensatory reflex movement of the eye in response to asymmetrical input from vestibular nerves. This occurs during movement of the head. The purpose of the vestibulo-ocular reflex is to control eye position in order to maintain a constant visual image during head movement (Shepard and Solomon, 2000).

Loss of vestibular function can have a detrimental effect on the well being of an individual. However, spontaneous recovery can be expected in many cases due to adaptation of the central nervous system to dizziness or vertigo, compensation of other sensory inputs, and equalization of vestibular nerves in response to asymmetrical input. Individuals with vestibular system dysfunction usually widen their stance and hold their arms out at their sides in order to increase their base of support during walking, but may
still be able to stand still with the eyes closed without symptoms (Shepard and Solomon, 2000).

Subjects with vestibular dysfunction who performed eye-head exercises under various conditions for 45 minutes, three times a week, as part of a rehab group showed improvements in standing balance. However, subjects who did the same exercises at home did not see any improvements after twelve weeks. This may have been due to a lower adherence rate or to performing the exercises incorrectly as the home exercise group was unsupervised (Szturm, Iveland, and Lessing-Turner, 1994).

In semi-tandem, tandem, and one-legged stance tests of subjects over the age of 75 years, subjects were 5.7 times more likely to experience loss of balance when they were blindfolded (Judge, King, Whipple, Clive, and Wolfson, 1995). Similarly, when compared to healthy controls, elderly with bilateral vestibular hypofunction are significantly less able to control their lateral momentum during normal gait (Kaya, Krebs, and Riley, 1998).

**Neural and Muscular Function**

Daubney and Culham (1999) found strength of ankle dorsiflexors and hip extensors to be significantly greater in fallers than in non-fallers. Ankle dorsiflexion and eversion muscle strength were also found to predict scores on the Berg Balance Scale, a test involving activities of daily living with up to 58% accuracy.

When recovering from a forward slip, both young and old adults activate the anterior and posterior thigh muscles. However, adults over 60 years of age showed a delay in the onset of reaction, as well as a longer duration and a smaller magnitude of
contraction according to Tang (1997), who used surface electromyographical recordings of the quadriceps and hamstrings during various walking surface perturbations.

Weak plantar flexion strength was found to be related to increased head movement in healthy subjects aged 21 to 77 years old. Range of movement of the limbs was assessed when a postural disturbance was provided via a moving platform. This postural response was most pronounced in the oldest subjects (Wu, 1998).

Wolfson et al. (1995) found knee flexion, knee extension, and dorsiflexion of fallers to be 47.9%, 61.3%, and 9.5%, respectively, of non-fallers. A postural stress test, which involved dropping a small percentage of a subject’s body weight on a pulley attached to a belt around the subject’s waist was used to determine balance strategies. The most efficient strategy to recover from such a perturbation is to move the head, trunk, and arms forward in order to counterbalance the backward motion. Lifting the toes (dorsiflexion) is important in further counterbalancing the backward motion.

Kou and Wajac (1993) used acceleration vectors based on the musculoskeletal model to determine which muscles should be strengthened in order to increase the body’s ability to make postural adjustments required for balance in normal activities. The muscles identified were the hamstrings, tibialis anterior, rectus femoris, and gastrocnemius. While it is generally accepted that these muscles are of importance for various balance strategies, it is unknown if strengthening alone will lead to timely coordination of muscle forces. Coordination of movements requires the adaptation of motor units through repetition and practice. It is still questionable whether increasing the strength of these muscles would cause an increase in power and speed as well.
In a study that involved releasing subjects from a forward lean position, subjects age 66 to 80 demonstrated delayed activation of the vastus lateralis, delayed deactivation of the rectus femoris, and prolonged activation of the soleus, gastrocnemius, and biceps femoris muscles compared to younger subjects who were recovering from the same leans. Overall response patterns were similar; only the timing of reaction was different between the two groups (Thelen, Muriuki, James, Schultz, Ashton-Miller, and Alexander, 1999).

Muscular endurance may play a role in balance, as well as strength. Subjects aged 20 to 39 years showed a decline in platform balance measures after fatiguing their leg muscles in a manner similar to stair stepping (Johnston, Howard, Cawley, and Losse, 1998). It may be assumed that similar effects would be seen in elderly subjects, who generally fatigue faster than do younger and middle-aged adults at the same absolute workloads.

Other Factors

Tinetti, Williams, and Mayewski (1986) found a relationship between the number of disabilities experienced in adults over the age of 60 and the number of falls experienced each year by the same individuals. The following characteristics were common in recurrent fallers: poor back flexibility, lack of lower-extremity strength, poor distant vision, symptoms of dizziness when turning the neck, impaired mental status, hearing problems, poor muscular endurance, impaired knee strength, and significant postural blood pressure drop. Balance and gait tests were helpful in distinguishing between recurrent fallers and non-fallers. Recurrent fallers had more difficulty rising or
sitting down, instability upon standing, and shorter, more variable steps than did non-fallers.

Tests of proprioception in the lower limbs, visual contrast sensitivity, ankle dorsiflexion strength, reaction speed, and amount of sway in the eyes-closed, normal stance position were found to distinguish between individuals who had never fallen and individuals who experienced multiple falls per year. Although it was not significant, quadriceps strength was also correlated with fall status in a study by Lord, Clark, and Webster (1991).

Shumway-Cook, Baldwin, Polissar, and Gruber (1997) showed no significant difference between balance scores of males and females over the age of 65. The same conclusion was drawn from a study that involved computerized testing of 255 subjects over the age of 70 on a posturography platform (Wolfson, Whipple, Amerman, Nashner, and Lewis, 1994).

A paper by Tinetti (1986) suggests that decreased functional mobility of older adults is due to the overlapping of several degenerative processes. Therefore, there is not always a consistent relationship between biomechanical abnormalities and resulting function (e.g., fall status). Because the relationship of factors contributing to fall status is so complex, therapeutic measures have historically been aimed at the dysfunctional symptoms, and not at the possible underlying causes of the symptoms.
Exercise Training and Balance

Crilly, Willems, Trenholm, Hayes, and Delaqueriee-Richardson (1989) found no improvements in the postural sway of women age 72 to 92 after they participated in an exercise program three times a week for twelve weeks. Although the article was unspecific in the exercise type, the exercises were aimed at improving breathing, single and double leg stance, coordination, flexibility, strength of the legs, trunk, and ankles, and general relaxation. However, subjects in this particular study were institutionalized, and therefore may have been incapable of improving within a time period of twelve weeks. It is also possible that these subjects were disabled to a point of irreversibility.

What may be more undesirable than seeing no improvement in balance is seeing a decrease in balance. It is important that when strength training is included in an exercise regimen, both agonist and antagonist muscle groups should be involved. Twenty-six young healthy subjects strengthened back extensor and hip flexor muscles via isometric contractions during intervals of 10 seconds contraction to 10 seconds rest for four minutes at a time, three times a day for one month. Postural control measured by force transducer plates decreased while high frequency control efforts for stability increased during postural sway on both hard and elastic surfaces during both eyes open and eyes closed conditions. Control efforts were measured using electromyographical recordings taken during the postural sway tests. When the subjects trained at home on wobble board
platforms for four minutes, three times a day for one month, postural stability increased and high frequency control efforts decreased (Kollmitzer and Ebenbichler, 2000).

Knee extension resistance training has been found to increase the ability of both middle-aged and elderly persons to move their center of gravity within their individual limits of stability, as measured by a computerized posturography system. Subjects trained for ten weeks, doing one set of eight to twelve repetitions until volitional fatigue occurred. The one repetition maximum for knee extension also did increase as a result of the strength training (Ryushi, Kumagai, Hayase, Abe, Shibuya, and Ono, 2000).

A study that compared strength training, cardiovascular training, strength plus cardiovascular training, and a control group yielded no significant differences between the effects of the three exercise regimens on balance in older adults. Balance testing included walking on a balance beam, standing on a tiltboard platform, timed stances, gait speed, and stair climbing speed. These tests were conducted before and after a six-month training period, in which subjects exercised for one hour three times a week. No significant differences were found in balance, gait, or health status for any group following the training period, however, post-training follow-ups revealed that all exercise groups had improved both fall rate and time to first fall compared to the control group (Buchner, Cress, Lateur, de Esselman, and Peter, 1997).

The amount of exercise that is necessary to reduce fall risk is undetermined, as it varies from one individual to another. However, a study that compared older adults who were fully adherent to those who were partially adherent (less than 75% attendance) to an individualized exercise program showed similar balance test scores between the two
groups. Both groups scored higher than a control group, which performed no exercise (Shumway-Cook, Gruber, Baldwin, and Liao, 1997).

Although all modes of exercise have the potential to improve balance in elderly participants, some research is devoted specifically towards balance exercise. The use of movable surfaces is often incorporated into such a routine. A nine-week training program, which included medicine ball exercises, balance board exercises, and trampoline exercise twice a week, yielded some positive results. The program also included head turning (i.e. vestibular exercises) (Kronhed, Moller, Olsson, and Moller, 2001).

Another study involved a computerized balance-training program, which was performed three times a week for eight weeks. This training required older subjects to shift their center of mass while standing on fixed and moving surfaces and resulted in improved balance and performance of daily activities (Rose and Clark, 2000).

Exercise Balls

Exercise balls, or “Swiss Balls,” were first developed in 1963. They have since been largely used in physical therapy settings for various purposes: Developing strength, flexibility, relaxation, balance reactions, and coordination. The ball also incorporates an element of enjoyment into the exercise (Posner-Mayer, 1995).

Sitting on the ball requires the center of gravity to be maintained over a mobile base of support. Proper posture, joint alignment, weight shifting, equilibrium reactions, and righting reactions must be utilized in order to maintain balance. The postural
muscles are continuously contracting in order to overcome gravity. In addition, movements on the ball displace the center of gravity, therefore, balance reactions are being further tested (Hypes, 1991). Posner-Mayer (1995) refers to sitting on the ball as "active sitting."

A recent study examined abdominal muscle response of young, fit subjects performing curl-ups on four different surfaces: floor, wobble board, exercise ball with feet on the floor, and exercise ball with feet supported on a bench. Rectus abdominus activity increased from 21% to 35% of maximal voluntary contraction, and external oblique activity increased from 5% to 10% of maximal voluntary contraction when subjects were performing curl-ups on the ball with their feet on the floor. In addition, the obliques assisted for longer periods of time while subjects were on the ball (Vera-Garcia, Grenier, and McGill, 2000).

Contraindications to the use of the exercise balls may include low-back arthritis or severe osteoporosis as spinal loads are increased significantly when using the ball (Vera-Garcia et al., 2000). Also many elderly individuals should not perform ball exercises unassisted because of the risk of falling. If another individual stabilizes the ball, less balance is required to stay on top of the ball and more exercises may be performed. The subject may progress by requiring stabilization of the ball less frequently (Hypes, 1991).

Balance Testing of Older Adults

MacRae, Lacourse, and Moldavon (1992) found the One-Legged Stance Test (OLST) and a Sit-to-Stand Test (STST) to be predicative of fall status. The OLST
involved standing unsupported on one leg for a maximum of 30 seconds while the STST timed subjects as they arose from a chair ten times.

Another study involving the OLST showed a decline in performance with age. (See Table 1.) Although the study does not provide normative values, these scores do indicate that the performance of older individuals is expected to be somewhat poor (Bohannon, Larkin, Cook, Gear, and Singer, 1984).

Table 1. Decreasing OLST Scores with Age

<table>
<thead>
<tr>
<th>AGE (years)</th>
<th>EYES OPEN OR CLOSED</th>
<th>MEAN SCORE (seconds)</th>
<th>% LESS THAN 30 SECONDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>20-39</td>
<td>Open</td>
<td>30.0</td>
<td>0</td>
</tr>
<tr>
<td>20-39</td>
<td>Closed</td>
<td>28.8±2.3</td>
<td>25</td>
</tr>
<tr>
<td>60-69</td>
<td>Open</td>
<td>22.5±8.6</td>
<td>57</td>
</tr>
<tr>
<td>60-69</td>
<td>Closed</td>
<td>10.2±8.6</td>
<td>90</td>
</tr>
<tr>
<td>70-79</td>
<td>Open</td>
<td>14.2±9.3</td>
<td>90</td>
</tr>
<tr>
<td>70-79</td>
<td>Closed</td>
<td>4.3±3.0</td>
<td>100</td>
</tr>
</tbody>
</table>

While the OLST is a sensitive measure of balance, it is also very difficult for most older individuals. Other researchers have also included semi-tandem and tandem (heel-to-toe) stance (TS) in addition to the OLST because they are less difficult to perform. Many subjects who have poor OLST scores can maintain the TS for 30 seconds (Judge, King, Whipple, Clive, and Wolfson, 1995).

Older adults who are more physically fit have higher OLST scores than those with poorer health. One study used a maximum of 45 seconds as opposed to the usual 30 second maximum in order to eliminate a "ceiling effect." The longer time limit would
allow for a more accurate portrayal of balancing ability in fit individuals (Briggs, Grossman, Birch, Drews, and Shaddeau, 1989).

Kronhed, Moller, Olsson, and Moller (2001) used walking 30 meters as fast as possible and walking heel-to-toe both forwards and backwards. In this study subjects were required to walk 30 meters as fast as possible while making one turn after 15 meters. Timing began and ended when the subject crossed the starting line. Tandem, heel-to-toe walks were conducted by having subjects first walk forwards on a three-inch wide stripe on the floor for up to fifteen steps, and then walk backwards between two stripes on the floor, which were placed six inches apart, for up to fifteen steps. The number of consecutive correctly placed steps was counted for both tests.

Strength Testing of Older Adults

Because older individuals are at an especially high risk of injury during maximal exertion, submaximal strength testing may be more appropriate for this group. In addition to risks involved, the trial and error method of one repetition maximal tests may fatigue the individual and therefore may be an inaccurate measure of strength (Kuramoto and Payne, 1995).

Submaximal Strength Testing

Various studies have been published in which submaximal strength tests have been shown to be predictive of maximal strength testing. Braith, Graves, Leggett and Pollock (1993) found that a test consisting of 7 to 10 repetitions performed to failure can
accurately predict the one-repetition maximum (1RM) of knee extension strength. However, the relationship between maximal and submaximal strength is different between trained and untrained individuals, as trained individuals may be able to lift a higher percentage of their 1RM during the 7-10 RM test than untrained individuals.

Abadie and Wentworth (2000) found similar results when comparing a 5-10 RM test to 1 RM tests of untrained females on the chest press, shoulder press, and knee extension. The 5-10 RM scores were predictive of the 1RM scores, and also produced less delayed onset muscle soreness than did the 1RM tests.

The sit-to-stand test is dependent upon leg strength, and is a functional daily activity. Subjects do not have to learn any new movements and are not overwhelmed by machinery. A positive correlation should exist between the number of sit-to-stand repetitions that can be performed and the muscular strength and endurance of the quadriceps, hamstrings, and gluteal muscles (MacRae, et al., 1992).
CHAPTER 3
METHODOLOGY

Subjects

Eleven apparently healthy subjects over age 60 years agreed to participate in this study. Six agreed to participate as a part of the exercise group (EG), and five agreed to participate as a part of the control group (CG). All subjects were informed about their involvement in this study and about the purpose of the study. All subjects completed a health history questionnaire (Appendix A) and read and signed an informed consent (Appendix B) before participating. All subjects were allowed to withdraw from the study at any time if they wished to do so. None of the subjects were classified as fallers and none were participating in any exercise routine regularly.

Exercise Group

Subjects in the exercise group were recruited from the Charleston Senior Center’s volunteer program by means of a flyer mailing and an advertisement in the Charleston newspaper. Eight seniors responded and came to an informational meeting. One subject was eliminated because he was unable to walk without an assistive device. Another subject requested to be placed in the control group. One male and five females agreed to participate in the balance training exercises.
Control Group

Because of a shortage of volunteers to perform the balance ball exercises, subjects for the control group were sought out individually from a local community church. After explaining the study and requesting participation in the balance testing over a telephone call, four additional subjects, one male and three females, agreed to participate. With the addition of the subject from the Senior Center, there were one male and four females who performed balance testing and chair stands during the pre-training and post-training time periods.

Study Design

This study involved a pretest-posttest model, in which a control group and an exercise group were compared. The control group did no regular exercise during the 10-week training period. The exercise group performed exercises using the Swiss Balls, or exercise balls during the same ten-week period. Change in test scores were compared between the two groups.

Testing of Subjects

All tests for the subjects recruited from the senior center were performed at the Charleston Senior Center, in Charleston, Illinois, and tests for the subjects recruited from the church were performed at the St. Mary’s Church hall, in Pesotum, Illinois. All tests were conducted on a one-on-one basis with an instructor in an area that was free of
distractions. Each subject was tested in the same manner. An instructor explained and demonstrated each test, and then the subject was given as many as three trials until each individual felt they were satisfied with their performance. The best of three trials was recorded. Subjects wore the same shoes during the pre-training and post-training testing.

**One-Legged Stance Test**

The subjects stood with their arms at their sides, looking straight ahead, and not touching any supporting object. Timing was recorded using a hand-held stopwatch. Timing began when the subject raised one foot off the ground and ended when the subject touched the raised foot to the supporting leg, placed the raised foot on the ground, displaced the supporting foot, or when 30 seconds had elapsed. There were four test conditions: right leg, eyes-open; left leg, eyes-open; right leg, eyes-closed; and left leg, eyes-closed. Each subject was allowed three trials for each test condition and the best score was recorded.

**Tandem Stand**

The subjects placed their feet in a heel-to-toe position on a masking tape line with their hands at their sides. Timing was recorded using a hand-held stopwatch. Timing began with the placement of the feet in the heel-to-toe position or with the closing of the eyes in the eyes-closed trials. Timing ended when the subject displaced either foot or reached the 30-second maximum. There were four test conditions: right foot in front with eyes open, left foot in front with eyes open, right foot in front with eyes closed, or left foot in front with eyes closed. Each subject was allowed three trials for each test condition and the best score was recorded.
Tandem Walk Forward and Tandem Walk Backward
Subjects walked forwards in a tandem, heel-to-toe, manner on a masking tape line for up to 15 consecutive steps without placing a foot off of the line. The number of steps taken without stepping completely off of the line was recorded. The subjects then walked backwards in the same manner for up to 15 consecutive steps without placing a foot outside of two masking tape lines that were placed six inches apart. The number of steps taken without stepping outside of the lines was recorded. Subjects were allowed three trials for each condition (forward and backward) and the best score was recorded.

Thirty-Meter Timed Walk
Two masking tape lines were placed 7.5 meters apart. Subjects walked at their normal walking pace, making three turns in order to complete the 30 meters. Timing was recorded using a hand-held stopwatch. Timing began when the subject crossed over the first line and ended when he or she returned to the starting line for the second time. Only one trial was allowed for the 30-meter walk.

Chair Stands
Chair stands were used as an assessment of leg strength, although it may more accurately portray muscular endurance. Subjects sat in a chair that allowed their knees to bend at a 90-degree angle while crossing their arms over their chest. Subjects were seated (weight on the chair) at the starting position of each chair stand and had fully extended knees and hips at the ending position of each chair stand. The tester told the subjects when to begin and counted the number of times the subjects rose from the chair within 30 seconds. The
tester told each subject when 10, 20, and 30 seconds had passed. Only one trial was allowed for chair stands.

Exercise Ball Training

All training was conducted at the Charleston Senior Center. The exercise group participated in 10 weeks of training, which utilized an exercise ball. Training progression was dependent upon individual ability levels, subject input, and the discretion of the investigator. Subjects were instructed to stop any exercise if it became painful at any time, and to inform the investigator of any injuries or discomforts.

The investigator trained subjects twice a week for approximately 15 minutes per training session. Each subject used a ball that was appropriate for his or her height. When each subject was seated on the ball, his or her hip and knees were bent at an angle of 90 degrees. Exercises involved shifting of body weight in various directions. More advanced exercises involved lifting one leg off of the floor while sitting on the ball. In addition, all subjects performed wall squats and an exercise that involved writing the alphabet in the air with the foot while sitting in a chair with the calf supported by the ball. Each of the following exercises was performed for approximately 30 seconds, with the exception of wall squats and alphabet writing.
Exercises

Basic Bounce.
Subject sits on the ball with both feet flat on the floor, knees bent at a 90-degree angle, shoulders tall, arms at their sides, and hips tucked. The subject pushes his or her feet into the floor and tightens the hip and thigh muscles in order to slightly lift the trunk and then relaxes and repeats these movements as vigorously as balance and coordination will allow.

Gentle Abdominals- Sitting
The subject sits quietly on the ball and turns the neck as far as possible to look over one shoulder before returning to center and repeating on the opposite side.

Gentle Trunk Rotation- Sitting
The subject, seated on the ball, slowly swings arms around the body as far as possible, while keeping the head, neck, and shoulders moving in the same direction. The subject returns to the staring position and repeats the movement in the opposite direction.

Front and Back Hip Roll
The subject rolls forwards and backwards as far as possible while remaining in the upright-seated position. The feet remain planted on the floor and the hips, knees, and ankles flex and extend in order to create movement.
Side to Side Hip Roll

The subject rolls the ball as far as possible from side to side while remaining in the seated position. Shoulders remain level and move as little as possible while the hips, knees, and ankles create movement. Feet remain planted on the floor.

Circular Hip Roll

The subject rolls the ball under the hip in a circular manner while remaining in a seated position. The hips, knees, and ankles provide movement while the shoulders and feet remain stable. The subject rolls first in a clockwise direction and then in a counterclockwise direction.

Marching

The subject sits in an upright position on the ball while lifting the right foot off of the floor. While the right foot is lifted, the left arm swings forward slightly. Limbs are lowered to the starting position and then the movement is repeated with the opposite limbs. The subject continues this pattern as if he or she were “marching.”

Wall Squat

The subject stands with his or her back to the wall, feet spread hip width apart, and toes pointing forward. The ball is placed between the wall and the subject’s back. The subject lets his or her back conform to the ball as it provides support during movement. The subject bends slowly at the hips knees and ankles as if he or she were sitting down
into a chair. The subject slowly lowers his or her body as far as possible within a pain-free range of motion and then slowly extends through the knees and hips to return to the starting position without locking the knees. The subjects were watched closely to ensure that proper squat form was used (e.g. knees did not bend beyond 90-degrees and knees remained behind the toes). The first time the subjects performed wall squats, each did ten repetitions. After the first week of training, subjects were allowed to progress by adding two to three repetitions when they felt that the exercise was getting easier. The maximum number of repetitions that was achieved by the subjects ranged from 15 to 25.

Alphabet-Chair
While seated in a chair, subjects place one leg on a ball, so that the supported ankle has a full range of motion. The subject then writes the alphabet with the toes of the unsupported limb. The exercise was then repeated with the opposite foot.

Squat and Rock
While sitting on the ball, the subject walks the feet forward while leaning backwards in order to roll the ball under the middle-back. While lying on top of the ball, the subject bends at the knees and hips in order to rock forward and backwards as the hips move downward in front of the ball in a pain-free range of motion. After squatting downward, the subject returns to a seated position by pushing with the legs and leaning forward as the ball rolls back underneath the hips.
**Single-Leg Lift**

The subject maintains a seated position on the ball while lifting one foot off of the floor. The foot remains suspended for a count of three to five seconds before the subject lowers the foot to the floor and repeats the exercise with the opposite leg.

**Push and Pull Sitting**

The subject remains seated on the ball in the single-leg lift position. When this position can be maintained, the subject rolls forwards and backwards on the ball, using the supporting leg to provide movement. The knee of the supporting leg does not bend beyond 90 degrees. The raised foot is lowered after rolling forwards and backwards three times, and then the exercise is repeated on the opposite side.

**Alphabet Sitting**

After the single-leg lift can be maintained for an extended period of time, the subject attempts to write the alphabet with the toes of the suspended leg. After completing the alphabet, the subject lowers the raised leg and repeats the exercise with the opposite leg.

**Back Extensions**

The subject lies facedown with the ball under his or her abdomen, with all limbs touching the floor for support. The head and neck remain in a neutral position as the subject looks toward the floor. The subject slowly raises the right arm and left leg simultaneously so that they are in natural alignment with the spine, and then slowly lowers them to the starting position. The movement is then repeated with the opposite limbs.
Progression

All subjects began with the basic bounce, gentle abdominals-sitting, gentle trunk rotation-sitting, front and back hip roll, side-to-side hip roll, circular hip roll, wall squats, and alphabet-chair exercises. Additional exercises were added when the instructor perceived that the subject was ready to progress. The subjects provided input about the level of difficulty experienced with each exercise in addition to the level of ability the instructor observed during each exercise. Exercises were performed as described by Posner-Mayer in *Swiss Ball Applications for Orthopedic and Sports Medicine* (1995) with the exception of marching, alphabet-chair, back extensions, and single-leg lifts.

Safety

In order to ensure the safety of the participants, only one subject performed the exercises at any time. The investigator stood near each subject in order to assist him or her if necessary while the exercises were being performed. When subjects demonstrated difficulty in performing an exercise, the investigator aided him or her by stabilizing the ball or by providing support if loss of balance occurred. The investigator did aid in loss of balance twice with one subject near the end of the training period. Each subject's health history questionnaire, physician's telephone number, and list of medications were readily available in case of an emergency.
Data Analysis

A multivariate data analysis was performed using an SPSS data processing system on a Unix mainframe computer at Eastern Illinois University. Means, standard deviations, variances, minimums, and maximums were calculated for each descriptive variable (age, height, and weight) and for each dependent variable (each pre-training and post-training test score). Change scores were calculated by subtracting pre-training scores from post-training scores, with the exception of the timed walk, which was calculated by subtracting post-training scores from the pre-training scores. This was because the timed walk scores were expected to improve in the training group after the exercise ball training. Difference in change scores between the exercise and control groups was then tested using a MANOVA.
Descriptive Data

Nine subjects completed the pre- and post-training tests. The exercise group consisted of one male and three females, and the control group consisted of one male and four females. Subjects included in exercise group data had at least a 75 percent participation rate. One subject had less than 75 percent attendance and another subject became ill before the post-training tests were done. Data from these subjects was not included. Most subjects reported that they enjoyed the ball exercises, with the exception of squat and rock and back extensions. When individuals reported that they did not like these two exercises, they were discontinued. No injuries occurred as a result of the ball training. Control group characteristics are listed in Table 2, and exercise group characteristics are listed in Table 3.

Table 2. Control Group Characteristics

<table>
<thead>
<tr>
<th></th>
<th>MEAN</th>
<th>STANDARD DEVIATION</th>
<th>MINIMUM</th>
<th>MAXIMUM</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGE (yrs)</td>
<td>71.6</td>
<td>+/-5.7</td>
<td>64</td>
<td>76</td>
</tr>
<tr>
<td>HT (in)</td>
<td>64.4</td>
<td>+/-2.1</td>
<td>63</td>
<td>68</td>
</tr>
<tr>
<td>WT (lbs)</td>
<td>167.6</td>
<td>+/-16.7</td>
<td>150</td>
<td>190</td>
</tr>
<tr>
<td>BMI</td>
<td>28.4</td>
<td>+/-2.4</td>
<td>27</td>
<td>33</td>
</tr>
</tbody>
</table>
Table 3. Exercise Group Characteristics

<table>
<thead>
<tr>
<th></th>
<th>MEAN</th>
<th>STANDARD DEVIATION</th>
<th>MINIMUM</th>
<th>MAXIMUM</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGE (yrs)</td>
<td>75.5</td>
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<td>77</td>
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<td>HT (in)</td>
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<td>WT (lbs)</td>
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<td>+/-25.2</td>
<td>115</td>
<td>170</td>
</tr>
<tr>
<td>BMI</td>
<td>26.8</td>
<td>+/-8.1</td>
<td>21</td>
<td>38</td>
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</tbody>
</table>

Testing Data

The mean and standard deviation were calculated for each test. Pre-training and post-training observations are listed in Table 4. Individual test scores are listed in Appendix C.

Table 4. Mean and Standard Deviation of Test Scores

<table>
<thead>
<tr>
<th></th>
<th>CONTROL PRE-TEST</th>
<th>CONTROL POST-TEST</th>
<th>EXERCISE PRE-TEST</th>
<th>EXERCISE POST-TEST</th>
</tr>
</thead>
<tbody>
<tr>
<td>One-Leg Stand (sec)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eyes Open, R leg</td>
<td>18.7 +/-12.7</td>
<td>14.9 +/-10.8</td>
<td>13.3 +/-12.3</td>
<td>16.1 +/-11.7</td>
</tr>
<tr>
<td>Eyes Open, L leg</td>
<td>8.3 +/-5.4</td>
<td>12.9 +/-11.0</td>
<td>4.6 +/-3.4</td>
<td>10.6 +/-12.9</td>
</tr>
<tr>
<td>Eyes Closed, R leg</td>
<td>7.6 +/-12.7</td>
<td>7.3 +/-12.9</td>
<td>4.9 +/-3.3</td>
<td>3.2 +/-1.8</td>
</tr>
<tr>
<td>Eyes Closed, L leg</td>
<td>6.6 +/-12.0</td>
<td>3.3 +/-4.6</td>
<td>2.6 +/-0.2</td>
<td>2.5 +/-0.4</td>
</tr>
<tr>
<td>Tandem Stand (sec)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eyes Open, R leg</td>
<td>25.6 +/-9.8</td>
<td>29.4 +/-1.7</td>
<td>12.6 +/-13.1</td>
<td>18.1 +/-14.0</td>
</tr>
<tr>
<td>Eyes Open, L leg</td>
<td>26.5 +/-7.9</td>
<td>27.0 +/-6.6</td>
<td>20.1 +/-11.9</td>
<td>19.6 +/-12.3</td>
</tr>
<tr>
<td>Eyes Closed, R leg</td>
<td>10.2 +/-11.7</td>
<td>8.9 +/-5.1</td>
<td>2.4 +/-1.8</td>
<td>5.1 +/-3.5</td>
</tr>
<tr>
<td>Eyes Closed, L leg</td>
<td>14.6 +/-9.7</td>
<td>7.9 +/-3.0</td>
<td>4.0 +/-1.9</td>
<td>4.9 +/-3.0</td>
</tr>
<tr>
<td>Tandem Walk (steps)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forward</td>
<td>10.6 +/-6.2</td>
<td>11.0 +/-4.6</td>
<td>6.5 +/-9.8</td>
<td>9.5 +/-6.6</td>
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<tr>
<td>Backward</td>
<td>8.4 +/-6.3</td>
<td>7.8 +/-5.4</td>
<td>8.8 +/-7.2</td>
<td>9.5 +/-6.4</td>
</tr>
<tr>
<td>30-Meter Walk (sec)</td>
<td>29.9 +/-5.1</td>
<td>30.9 +/-6.4</td>
<td>40.1 +/-12.4</td>
<td>35.3 +/-12.9</td>
</tr>
<tr>
<td>Chair Stands (reps)</td>
<td>10.8 +/-2.5</td>
<td>11.2 +/-1.9</td>
<td>8.5 +/-1.7</td>
<td>12.0 +/-2.2</td>
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</tbody>
</table>
The results of the MANOVA tests for differences in change scores between the control group and the exercise group are listed in Table 5. There were significant group differences for the 30-meter walk and for chair stands, both of which were more improved in the exercise group.

Table 5. MANOVA Tests for Differences in Change Scores

<table>
<thead>
<tr>
<th></th>
<th>CONTROL</th>
<th>EXERCISE</th>
<th>P VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>One-Leg Stand (sec.)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eyes Open R Leg</td>
<td>-3.4 +/-8.1</td>
<td>2.8 +/-2.8</td>
<td>.172</td>
</tr>
<tr>
<td>Eyes Open L Leg</td>
<td>4.6 +/-7.3</td>
<td>6.1 +/-10.4</td>
<td>.812</td>
</tr>
<tr>
<td>Eyes Closed R Leg</td>
<td>-0.4 +/-0.5</td>
<td>-1.7 +/-1.7</td>
<td>.140</td>
</tr>
<tr>
<td>Eyes Closed L Leg</td>
<td>-3.3 +/-8.0</td>
<td>-0.2 +/-0.5</td>
<td>.463</td>
</tr>
<tr>
<td><strong>Tandem Stand (sec.)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eyes Open R Leg</td>
<td>3.7 +/-8.4</td>
<td>5.5 +/-6.7</td>
<td>.747</td>
</tr>
<tr>
<td>Eyes Open L Leg</td>
<td>0.6 +/-1.3</td>
<td>-0.5 +/-6.2</td>
<td>.714</td>
</tr>
<tr>
<td>Eyes Closed R Leg</td>
<td>-1.3 +/-7.7</td>
<td>2.7 +/-1.7</td>
<td>.348</td>
</tr>
<tr>
<td>Eyes Closed L Leg</td>
<td>-6.7 +/-6.8</td>
<td>0.9 +/-2.3</td>
<td>.072</td>
</tr>
<tr>
<td><strong>Tandem Walk Forward</strong></td>
<td>0.4 +/-2.2</td>
<td>3.0 +/-5.4</td>
<td>.351</td>
</tr>
<tr>
<td>(steps)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Tandem Walk Backward</strong></td>
<td>-0.6 +/-3.3</td>
<td>0.8 +/-1.5</td>
<td>.476</td>
</tr>
<tr>
<td>(steps)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td><strong>30 Meter Walk (sec.)</strong></td>
<td>-1.0 +/-2.5</td>
<td>4.8 +/-2.4</td>
<td>.010*</td>
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<tr>
<td><strong>Chair Stands (reps.)</strong></td>
<td>0.4 +/-1.3</td>
<td>3.5 +/-0.6</td>
<td>.004*</td>
</tr>
</tbody>
</table>

*Indicates a significant group difference

Expectations of the Study

Some factors affecting the balance of older adults are likely to persist even though an older individual is exercising. The older adult must learn to overcome or to function with some disability in many cases. For example, although an individual may begin strengthening exercises for the scapular retractors, it is most likely that postural deformities that have been present for a period of years will not be alleviated. Stooped or
rounded shoulders will still be present in individuals who have overstretched postural muscles and in those who may have spinal joint and ligamentous deterioration, although strengthening of the scapular retractors may help to alleviate pain in the upper back area.

One purpose of the ball exercises in this study was simply to create an awareness of posture during movements that challenge balance. Some muscular endurance and flexibility of postural muscles may have improved as a result of training; however, this is unknown as no testing was conducted to evaluate changes in the postural muscles.

Fear of falling, although not addressed in this study, is also an important factor contributing to fall status. Maki et al. (1994) found that subjects who fell were more likely to have greater fear of falling. It is unknown whether falling contributes to deceased confidence or if decreased confidence causes older individuals to be less active and deteriorate physically. One exercise subject in this study reported increased self-confidence when walking on sidewalks near her home after completing six weeks of training.

It was hoped that shifting of body weight while sitting on a mobile surface (e.g. the ball) would improve the subjects’ awareness of their own limits of stability and improve the timing and coordination of righting reactions in response to postural sway during situations in which balance is a challenge (e.g. one-legged stance, tandem stance, and tandem walks forward and backward). Chair stands and the 30-meter walk were expected to improve as a result of ball training due to increased leg strength and endurance from rolling the ball while seated and performing wall squats.

Recent evidence suggests that postural adjustments of the trunk are necessary to stabilize the spine before movement of the lower limbs. The transverse abdominus is
particularly important as it is the first of a series of trunk muscles activated prior to limb movement. This is most likely important during unperturbed walking as well as during recovery from loss of balance (Hodges et al., 1997).

Judge et al. (1995) reported that subjects over the age of 75 were more likely to experience loss of balance during balance tests in which they were blindfolded. This is most likely due to vestibular deterioration. Szturm et al. (1994) found improvements in standing balance of subjects who performed eye-head exercises for 45 minutes, three times a week. Some eye-head exercises were included in the exercise ball training of this study, although the duration of these exercises was much shorter. Improving vestibular function was not the main objective of the training, although it was considered. The head-turn exercise and the trunk rotation exercise were included in order to address any existing vestibular dysfunction. Each of these exercises was performed for approximately 30 seconds. The subjects did not find any difficulty in performing these exercises, however they did report that they enjoyed the stretching sensation that these exercises provided.

Discussion of Results

Hausdorff et al. (1997) found that walking speed of elderly fallers was significantly slower than that of non-fallers. Wolfson et al. (1995) found similar results when comparing walking speed and stride length of fallers and non-fallers. Kronhed et al. (2001) found increased walking speed and increased one-legged stance scores in subjects who participated in balance exercises three times a week for 60 minutes. MacRae et al. (1992) found a sit-to-stand test mean time of 22.6 seconds for 10 chair
stands in subjects with an average age of 73 years. This score is similar to averages of 8.5 to 12 chair stands within 30 seconds found in this study. Although tests of balance did not show any significant differences between the exercising subjects and the control subjects in this study, the eyes-closed tandem stand with right foot in front was close to being significantly different (p = .07). Perhaps if more subjects had been included in this study, the balance testing results would have revealed more significant differences. The timed 30-meter walk and number of chair stands completed within 30 seconds did improve significantly more in the exercise group than in the control group (p = .010 and p = .004 respectively) as was expected.

Because of the small subject number in this study, it was unlikely to see any statistically significant group differences in test scores. Follow-up studies should be conducted with a larger subject number. In addition, the sample of the older population should be more random, as these particular subjects came from two specific groups of older individuals.

The fact that the chair stands and 30-meter walk scores improved significantly shows that the subjects who participated in the ball exercises may have decreased their fall risk because of increased walking speed and increased muscular strength and endurance of the leg muscles. In addition, the gait test in this study involved three turns, as opposed to one or no turns used in the studies discussed previously. The turning involves some maneuvering of body position that is not involved in normal walking. Therefore, subjects with poorer balance would have more difficulty maneuvering the turns involved in this 30-meter walk test.
It is uncertain whether the difference in change scores on the 30-meter walk stemmed from increased balance or from increased muscular strength or endurance. Because subjects in the exercise group were able to complete a greater number of chair stands during the post-training test than the control subjects, it may be speculated that there were increases in muscular strength and endurance of the quadriceps and hamstring muscle groups. However, because leg strength was not directly measured, it is impossible to determine what factors contributed to the difference in scores. In addition to increased muscular strength, neural adaptations to the wall squats may be assumed to have aided the exercise subjects in improving their chair stand scores.

Because leg strength and walking speed are two factors that have a strong relationship with balance, it may be assumed that if chair stands and 30-meter walk scores improved significantly more in the exercise group, that other balance scores should be expected to improve as well. Most of the mean test scores did improve in the exercise subjects, although this improvement was not statistically different from the control group.

The OLST scores were similar to those found by Bohanon et al. (1984) who found mean scores of 14.2 and 4.3 seconds respectively for eyes open and eyes closed conditions. Most subjects had a great degree of difficulty performing the OLST with their eyes closed. Judge et al. (1995) reported that the OLST with eyes closed is a very sensitive measure of balance. A ceiling effect was not observed in Tandem Stance scores as was reported by Briggs et al. (1989). Therefore, a longer time limit of 45 seconds was not necessary in the present study.
The purpose of the exercise ball training in this study was to determine if a simple non-strenuous method of exercise could be used to improve the balance of older adults. The training was meant to be non-time consuming and enjoyable in nature in order to promote adherence to exercise. Most of the participants in the training commented that they did enjoy the ball exercises and would like to continue the exercises at home.

Other studies that have focused on balance training required a more time consuming regimen, although the time frames of eight to twelve weeks were similar. Training studies mentioned previously involved exercise sessions that were 45 to 60 minutes in duration, and were performed two to three times per week. The exercise sessions in this study were much shorter, only 15 minutes in duration. Perhaps if the sessions were longer, the improvements in balance would have been more significant. Future studies should be conducted with a larger sample in order to determine whether or not this less time-consuming exercise regimen is feasible for improving the balance of seniors.

Future studies should also address standing posture and the strength of postural muscles in response to exercise ball training. Training of the trunk stabilizers may be of particular importance as there is no research available on the effects of such training on older adults. Likewise, there is no current research on the long-term effects of exercise ball training on the balance, posture, gait, and strength of older individuals.
CHAPTER 5
CONCLUSION

Loss of balance is a major concern among the elderly population. As individuals age, they tend to become increasingly sedentary, which contributes to impaired balance. As balance continues to deteriorate, elderly individuals continue to become less active for fear of falling. A vicious cycle is in effect.

Exercise has been shown to improve the balance of older individuals. The effect of many different modes of exercise on the balance of seniors has been researched. Training on labile surfaces is often used because it is specific to balance. Exercise balls, or Swiss balls are one type of mobile surface that has not been researched in its application to the balance of older individuals. The purpose of this study was to determine if the use of a non-strenuous, time efficient exercise ball regimen may be effective in improving the balance of seniors.

Eleven subjects participated in this study. All subjects were classified as non-fallers and were not participating in any other regular exercise program. Four subjects, one male and three females, trained on exercise balls with the investigator for ten weeks. Training sessions were conducted on an individualized basis and were held twice a week for approximately 15 minutes each day. Subject participation required was at least 75 percent attendance of sessions. Five subjects, one male and four females, agreed to participate as part of the control group, which did not exercise during the ten-week period.
Although the two groups had similar characteristics, the exercise group was slightly older than the control group. A larger population sample would help to accommodate this difference, and a more random sample would aid in selecting subjects with a variety of different lifestyles. The subjects in this study were all volunteers. The exercise group resided mostly in the community of Charleston, Illinois, whereas the control group subjects resided in rural homes. All subjects were sedentary, except for the exercise group performing the ball exercises.

Balance testing of all subjects was conducted before and after the training period. Balance tests included one-legged stance, tandem stance, heel-to-toe (tandem) walking, a timed 30-meter walk, and chair stands. Mean scores, standard deviation, variance, minimums, and maximums were calculated for each balance test. Change scores were calculated and a Multivariate Analysis of Variance (MANOVA) test was completed to determine any significant group differences in test scores.

Significant differences between groups were found in change scores for the 30-meter walk (p = .010) and for chair stands (p = .004), both of which were higher in the exercise group. All balance test score changes were insignificant. More significant change scores may have been found, had there been more subjects in each group. Future studies should also consider the amount and duration of training that is needed to improve the balance of older individuals. This particular study required a minimal amount of 75 percent participation in the exercise program twice a week for ten weeks. Perhaps the exercises should have been performed three times a week or perhaps they should have been performed for twelve or more weeks. Many older adults, like younger populations, feel that they are unable to commit to long exercise sessions or daily exercise regimens.
Because the ball is a mobile surface, individuals must make postural adjustments and learn balancing strategies while sitting or moving on the ball. This study has shown improved gait and ability to rise from a chair as a result of exercise ball training. The exercise ball, or Swiss ball, has great potential for the use of balance training in older individuals.
REFERENCES


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Tinetti, M.E., Williams, T.F., and Mayewski, R. (1986). Fall risk index for elderly patients based on number of chronic disabilities. The American Journal of Medicine, 80, 429-434.


APPENDIX A

HEALTH HISTORY QUESTIONNAIRE

Name: ____________________________
Address: ____________________________
City ____________________________ Zip Code _____
Telephone: ____________________________
Birth Date: __/__/____ Age: _____
Gender: _____Male _____Female
Height _____ Weight _____
Physician's name: ____________________________ Telephone: ____________________________
Emergency contact: ____________________________ Relationship: ____________________________
Home phone: ____________________________ Work phone: ____________________________

Personal Medical History:

Do you have a recent or past history of any of the following?

___ heart disease/cardiac surgery
___ irregular heart beats
___ chest pain
___ heart attack
___ pulmonary disease (bronchitis, emhasema, etc.)
___ stroke
___ diabetes
___ epilepsy
___ high cholesterol
___ osteoporosis
___ fractures within the past 10 years:

___ high blood pressure
___ cancer
___ type: ____________________________
___ back pain
___ joint pain: ____________________________
___ migraines headaches
___ asthma
___ arthritis
___ lightheadedness/fainting
___ allergies
___ fatigue

Please list any surgeries you have had and the date each surgery took place: __________________________________________

Please list any medications you are currently taking: __________________________________________

Are you allergic to any medications? _____Yes _____No If yes, please list: ____________________________

During the past year, how many falls have you experienced? _____
Please explain each fall briefly: __________________________________________

Do you use an assistive device, such as a cane or walker? _____Yes _____No
If yes, when you use it: __________________________________________

Please list any surgeries you have had and the date each surgery took place: __________________________________________

Do you have any medical limitations that would restrict your participation in activity?
Yes ___ No ___ If yes, please list: ______________________

Do you currently exercise on a regular basis? Yes ___ No ___
If yes, please explain what you do on a weekly basis. ______________________

I have read, understood, and completed this questionnaire. Any questions that I had were answered to my full satisfaction.

Name ______________________

Signature ______________________ Date ______________________
APPENDIX B

Informed Consent for Participation in Balance Training Study

Stephanie Happ, who is a graduate student at Eastern Illinois University, has requested my participation in a research study. The title of the research is “The Effects of Exercise Ball Training on Balance in Older Adults”.

The purpose of the research is to find out if using exercise balls helps improve balance in seniors. Balance decreases in adults as a part of the normal aging process. The goal of training on exercise balls is to improve balance.

My participation will involve training at the Charleston Senior Center two times a week for about 15 to 20 minutes each day. The training period will last 10 weeks (March 20-May 25). For safety reasons, the training will progress at my own pace. Training on exercise balls involves sitting, bouncing, and rolling the ball under the body, all of which requires balance. The instructor will perform each exercise to show proper form, and then she will aid me in doing the exercise. (If I agree to be in the control group, I will not do any ball training and will not do any exercise that is new to me until after the second round of testing.)

My participation will involve balance testing. These tests will be done one week before and one week after the training in order to compare the results and find improvements. Balance testing involves standing on one leg, standing heel to toe, walking forwards and backwards on a line, and a 30-meter walk. An instructor will explain and show how each of these tests is done in order to ensure that they are performed safely and properly. These tests will take about 30 minutes.

I understand that my participation in this study requires that I attend the training sessions for 10 weeks if I am in the training group. I also will not change my activity level during this time. For safety purposes, the ball exercises are to be performed only with the instructor and not on my own.

I understand that there are some risks involved if I agree to participate in this study. The possible risks include falling and any injury that may result from a fall, such as sprains and broken bones. In addition, bouncing on the ball may irritate arthritis in the lower back if I already suffer from arthritis in this area. If this occurs, I should not continue participating in the ball exercises.

I understand that the possible benefits of my participation in the research include learning more about balance and the effects of exercise on balance. My balance may also improve as a result of the training. By completing this study, I will help professionals to better understand the use of the ball as a tool to improve balance.
I understand that the results of this research may be published, but that my name or identity will not be revealed. In order to maintain confidentiality of my records, Stephanie Happ will randomly assign a number to each participant. Participants will only be identified by that number and not by name in published materials. No one will have access to the name or to any other confidential information associated with the subject number.

If I have any questions concerning the research study or my participation in it, before or after my consent, they will be answered by Stephanie Happ, 47 1/2 Madison Ave., Charleston, IL 61920, telephone: 217-345-6263.

I understand that in case of injury, if I have any questions about my rights as a subject in this research, or if I feel that I have been placed at risk, I can contact Dr. Phyllis Croisant, Eastern Illinois University, 1020 McAfee Building, Charleston, IL, 61920, telephone, 217-581-7596.

I have read the above information. The nature, demands, risks, and benefits of the project have been explained to me. I knowingly assume the risks involved, and I understand that I may withdraw my consent and discontinue participation at any time without penalty. In signing this consent form, I am not waiving any legal claims, rights, or remedies. A copy of this consent form will be given to me.

Subject’s signature ______________________ Date ________________

I certify that I have explained to the above the nature and purpose, the potential benefits, and possible risks associated with participation in this research study, have answered any questions that have been raised, and have witnessed the above signature.

These elements on informed consent conform to the Assurance given by Eastern Illinois University to the Department of Physical Education to protect the rights of human subjects.

I have provided the subject with a copy of this signed consent document.

Signature of investigator ______________________ Date ________________
# APPENDIX C

## Control Group balance testing Scores

<table>
<thead>
<tr>
<th>Subject number</th>
<th>1</th>
<th>1</th>
<th>2</th>
<th>2</th>
<th>3</th>
<th>3</th>
<th>4</th>
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<tr>
<td><strong>Pre-training or Post-training</strong></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>OLS- open, dominant leg (sec.)</td>
<td>17.0</td>
<td>27.8</td>
<td>30.0</td>
<td>11.9</td>
<td>7.8</td>
<td>21.5</td>
<td>3.4</td>
<td>4.2</td>
<td>7.0</td>
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<td>OLS, closed, dominant leg (sec.)</td>
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<td>2.3</td>
<td>1.1</td>
<td>2.7</td>
<td>3.6</td>
<td>5.6</td>
<td>6.5</td>
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<td>OLS, closed, non-dominant leg (sec.)</td>
<td>28.0</td>
<td>10.7</td>
<td>2.7</td>
<td>5.0</td>
<td>2.3</td>
<td>0.9</td>
<td>0</td>
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<td>TS, open, right in front (sec.)</td>
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<td>30.0</td>
<td>30.0</td>
<td>30.0</td>
<td>30.0</td>
<td>30.0</td>
<td>30.0</td>
<td>30.0</td>
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<td>30.0</td>
<td>30.0</td>
<td>30.0</td>
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<td>7.2</td>
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<td>18.0</td>
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<td>6.4</td>
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<tr>
<td>Heel-to-Toe Walk, forward (steps)</td>
<td>15</td>
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<tr>
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<td>31.3</td>
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<td>10</td>
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Exercise Group Balance Testing Scores

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<th>OLS, open, non-dominant leg (sec.)</th>
<th>OLS, closed, dominant leg (sec.)</th>
<th>OLS, closed, non-dominant leg (sec.)</th>
<th>TS, open, right in front (sec.)</th>
<th>TS, open, left in front (sec.)</th>
<th>TS, closed, right in front (sec.)</th>
<th>TS, closed, left in front (sec.)</th>
<th>Heel-to-Toe Walk, forward (steps)</th>
<th>Heel-to-Toe Walk, backward (steps)</th>
<th>30-Meter Walk (sec.)</th>
<th>Number of Chair Stands in 30 sec.</th>
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<td>Pre</td>
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<td>2.8</td>
<td>3.6</td>
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<td>30.0</td>
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<td>3.1</td>
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