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The Effects of Square-Stepping Exercise on Risk of Falling and Balance in Senior Adults

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Introduction

As people age, their body systems gradually deteriorate. Muscle function and the vestibular system slowly deteriorate leading to lower body instability. The vestibular system provides a sense of balance and spatial awareness of the body to stabilize posture. Therefore, since the vestibular system diminishes, dizziness and imbalance become more prevalent in older adults. Older adults who struggle with dizziness and imbalance are more prone to falling. A study showed that in the United States, 24% of people older than 72 experience dizziness (Shinichi & Tatsuya., 2015). Dizziness and imbalance cause falls, and falls are the leading cause of hospitalization and accidental death in older adults (Shinichi & Tatsuya, 2015). An interview-based survey among residents of a senior community recorded that 35% of the residents had fallen at least once the year before (Shigematsu, Okura, Sakai & Rantanen, 2008). Among the same population, 53% of falls were caused from tripping. Trip-related falls are responsible for many hip fractures as well (Pavol, Owings, Foley & Grabiner, 2001). The aging process causes a major reduction in balance, agility, coordination, and muscle strength which impairs mobility. Research shows, decreases in these components are related to an increase in falls in the elderly population (Rodrigues et al., 2014). Thankfully, it is possible to prevent and reduce the risk of falls through balance training. It is crucial that older adults take the steps needed to improve their balance and therefore reduce their risk of falling. In addition, balance is a necessary component of fitness that is critical in executing daily tasks and adapting to the environment (Teixeira, C. L., Gobbi, S., Pereira, J. R., Ueno, D. T., Shigematsu, R., & Gobbi, L. B., 2013a).

Balance training

Skeletal muscle must be trained on a regular basis in order to maintain its strength and flexibility. The principle of overload declares that a greater than normal stress on the body is obligatory for a training adaptation to occur. The body will adapt to this stimulus as it is gradually overloaded. After the initial adaptation, a different stimulus is then required to continue improvements. In order for a muscle to increase strength, it must be progressively stressed by working against a load greater than accustomed to (Quinn, E, 2016). Similarly, the human body's balance system must be challenged in order to prevent falls, build confidence, and allow for independent living. Several types of exercises have been shown to increase balance. Such exercises include rapid plyometrics, martial arts, pilates, yoga, tai chi, and qigong.

Types of Balance Training

Plyometric training is a series of rapid and explosive exercises that involve the entire body. They build power, coordination, balance, and stability and are often designed for athletes. Most plyometrics involve advanced moves that require accurate timing, coordination, and adequate physical strength (Radcliffe & Farentinos, 2002).

A more relaxed, but still rigorous activity for improving balance and coordination for the non-athlete is an exercise called Pilates. Pilates emphasize the importance of breathing with movement to enhance the mind-body connection to reduce stress and tension. When practiced regularly, Pilates also increases flexibility, improves core strength, poor posture and other structural problems, and may reduce lower-back pain. Pilates routines can range from very gentle to higher intensity, with some moderate and advanced Pilates classes providing cardio benefits along with strength and flexibility (Isacowitz, 2006).

Another type of balance training that requires intense concentration is martial arts. Popular forms include Kung Fu, Karate, Capoeira, Judo, and even boxing. Most of these are highly physically demanding, very competitive, and involve physical contact with an opponent. They provide a full body workout, are an excellent source of balance training, improving energy, self-esteem, discipline, and self-defense skills (Iedwab & Standefer, 2000).

Tai Chi is a soft, gentle practice of Chinese origin that emphasizes balance, concentration, and fluid movements. Although it's technically a martial art, it is non-contact so the focus is on one's own slow, repeated, and meditative movements. Tai Chi has been proven to build strength, flexibility, and balance, and may benefit medical conditions including arthritis, hypertension, heart disease, sleep problems, stress and anxiety, and improve quality of life for cancer patients (Crompton, 2000). One study evaluated the influence of a Tai Chi program with senior adults. Fifteen participants participated in a Tai Chi program for ten weeks to assess the effects of Tai Chi on health-related quality of life, functional mobility, and balance performance. The participants were tested using the Timed Up-and-Go (TUG) test, One-Leg Stance, Functional Reach (FR), and a self-reported Health Related Quality of Life (EQ-5D). Improvement was seen regarding the EQ-5D. There was higher amount of self-care, more activities, less pain and anxiety/depression post intervention. There were also significant improvements in the TUG and One-Leg Stance tests (Roberson, D. N., Wang, S., Sigmund, E., & Valkova, H., 2015). In conclusion, this ten week Tai Chi intervention had beneficial effects on self-reported health-related quality of life, functional mobility, and balance performance.

Like Tai Chi, Qigong is also a Chinese martial art that focuses on energy. Qigong is different from Tai Chi in the sense that it's even gentler, the movements are simpler, and it is

more adaptive in the sense that literally anyone who can take deep breaths can practice Qigong in some form. This exercise is less difficult than Tai Chi and its primary focus is stress reduction and relaxation, but it can also improve balance (Connor & Tse, 1992).

Yoga, a term that has been used for centuries, is a derivation of the word yuj, which means yoking, often interpreted as meaning union. Yoga is said to be for the purpose of uniting the mind, body, and spirit. The physical practice of yoga is known as asana. Contrary to what many people may think of yoga, it is more than just stretching. While stretching is certainly involved, yoga focuses on creating balance in the body through developing both strength and flexibility. This is done through the performance of poses or postures, each of which has specific physical benefits. The poses can be done quickly in succession, creating heat in the body through movement or more slowly to increase stamina and perfect the alignment of the pose. The poses are similar in each form of yoga, but the approach to them varies depending on the yoga tradition in which the yoga instructor has been trained (Iyengar, 2008).

Despite the energy and variety these aforementioned exercises bring, they fail to fit some people's needs, in particular, the elderly. The elderly population is most susceptible to losing their balance and suffering a fall because balance decreases with age. However, the elderly are unable to engage in most of the activities and sports that are known to increase balance. Activities like plyometrics, pilates, martial arts, and some yoga exercises are too complicated for most senior adults. The balance training programs that focus on improving balance in older adults must be more suitable for the older body but still effective in challenging the neural and muscular systems in order to produce results.

Square-Stepping Exercise

There are many studies that have investigated balance training programs in older adults like the Tai Chi, Yoga, and Qigong mentioned previously. Another program worth investigating is the square-stepping exercise (SSE) program. The program consists of performing patterns on a mat that involves a series of forward, backward, lateral, and diagonal steps; this program has been proven to improve balance in older adults. It is feasible and low in cost, and it not only has been shown to improve functional fitness, but also cognitive and depression symptoms (Shigematsu, Okura, Sakai & Rantanen, 2008).

Studies have analyzed the effect of SSE on balance and functional fitness in older adults. It has been shown to be an effective means of fall risk reduction through balance training. This program was created by Shigematsu and Okura in Japan to improve balance and reduce the risk of falls (Teixeira et al., 2013a). The founders conducted a study consisting of 86 community-dwelling older adults where they compared the effects of square-stepping exercise and basic exercises on functional fitness in four groups of older adults. One group practiced only SSE, the second group practiced basic exercises, the third group practiced both SSE and basic exercises, and the fourth group was a control group. Results indicated that SSE sequences are just as effective as the basic exercise and combined exercise intervention groups. On the Berg Balance Scale (BBS), the basic exercise group improved the most, and on the Timed Up and Go (TUG) test the square-stepping exercise group significantly improved. Meanwhile, the control group worsened over the 16-week study in both BBS and TUG (Teixeira et al., 2013a).Those who engaged in basic physical exercises improved in agility and aerobic endurance while SSE improved in balance. They concluded that, either practiced alone or together, SSE and basic

exercise have a positive influence on functional fitness of older adults. Thus, SSE is an alternative, effective type of balance training.

A study evaluating the effects of SSE on balance and depressive symptoms in older adults shows complementary findings. This study involved one group participating in SSE while the other group did not engage in any form of exercise. TUG and BBS were administered and showed similar results. TUG times decreased for the training group and increased for the control group. It is obvious how a program involving multi-directional steps can improve balance (Rodrigues et al., 2014).

Another study by Shigematsu and Okura (Shigematsu, Okura, Sakai & Rantanen., 2008) revealed similar results showing that SSE is just as effective as other strength and balance (SB) training interventions. Thirty-nine community-dwelling older adults were involved in this study. The participants were randomly placed in either the SSE group or the strength and balance training group. The intervention sessions lasted 70 minutes and occurred twice a week over a 12 week period. The results showed that SSE positively affects static balance, agility, and walking speed. This study even suggests that SSE training is better than SB training in preventing falls due to the quick leg movements that occur during SSE training (Shigematsu, Okura, Sakai & Rantanen, 2008). Each participant was tested with a 9-item test battery assessment of physical performance to measure the efficacy of the interventions. Then, fourteen months after the intervention, the number of falls of each participant were reported. The falls were self-reported and were defined as a sudden, unintentional change in position causing the subject to land at a lower level, and not caused by an outside force. This study showed that the number of falls and the rate of falls per trip reported in SSE training were lower than in the SB training. Both of

these studies demonstrate the capability of square-stepping exercise on balance and functional fitness (Shigematsu, Okura, Sakai & Rantanen, 2008).

A similar study conducted by Sharma Vinita, Yadav Joginder,and Kalra Sheetal (2016) also compared the effect of square stepping exercise and balance and strength training on risk of fall and dynamic balance in the elderly population. One group of 15 participants engaged in SSE intervention while fifteen other participants engaged in other strength and balance training over twelve weeks. The 9-item test battery assessment of physical performance and the Berg Balance Scale were used to test balance. Data was collected at baseline, and at the end of the fourth week, eighth week, and twelfth week of the study. The researchers concluded that risk of fall decreased significantly in the square-stepping exercise group as compared to strength and balance training group. Dynamic balance also improved significantly in SSE than compared to the strength and balance group. The results of this study revealed that both treatment techniques were effective in improving dynamic balance and reducing risk of fall; however, statistically, there was a significant difference between both the groups at the end of eighth and twelfth week. The significant difference suggests that square stepping exercises is a more effective intervention compared to strength and balance training in reducing the risk of fall and improving dynamic balance (Vinita, S., Joginder, Y., & Sheetal, K., 2016).

Not only has SSE been shown to improve balance, but it also has been reported to improve cognitive function in a study by Teixeira and colleagues (Teixeira et al., 2013a). SSE training involves visualizing and memorizing a specific sequence and then executing that sequence on a mat. A task like this requires focus, memory, and thinking ahead to correctly complete it. These researchers studied the effects of SSE on cognitive functions in older people.

Participants were divided into two groups: participants who practiced SSE sequences for 16 weeks, and a control group who did not engage in SSE. Each participant was tested on pre and post intervention tests that evaluated general cognitive status, short-term memory, and the ability to mentally manipulate information. On the Modified Card Sorting Test (MCST), there was a significant improvement in the SSE group. On the Mini-Mental State Examination (MMSE), the SSE group enhanced global cognitive status (Teixeira et al., 2013b). The same study involving the effects of SSE on balance and depressive symptoms in older adults also showed improvements in the MMSE as well. This study also discovered a positive effect of square-stepping exercise on depressive symptoms in older adults. The Geriatric Depression Scale-short form (GDS-15) was also administered during this study. The GDS-15 assesses depressive symptoms among the participants. After the 16-week training program, there was no significant decrease on depressive symptoms for the training group; however, a significant increase of depressive symptoms was observed for the control group. The control group was physically inactive and therefore showed worse symptoms in the post-test. One reason for this may be that the training group experienced interaction with others during training sessions which can reduce stress and feelings of isolation (Rodrigues et al., 2014). As shown in these studies, SSE has been shown to enhance physical and cognitive abilities, and improve depressive symptoms.

Obviously, many studies have evaluated the effects of SSE on balance in older adults. These studies have used measures such as the Timed Up and Go Test, the Berg Balance Scale, which tests static and dynamic balance abilities (American Academy of Health and Fitness, n.d.), and the Functional Reach Test (Rehab Measure Database, n.d.). These tests are easy to perform,

but they lack true accuracy in predicting fall risk and balance abilities. Therefore, this creates a gap in the literature as a more effective instrument should be used. A highly effective instrument for measuring balance abilities is the Biodex Balance System, which is able to analyze balance through assessing neuromuscular control by quantifying the ability to maintain dynamic bilateral and unilateral postural stability on a static or unstable surface (Biodex Medical Systems, 2012). This system is extremely versatile and is the only system to provide a fall-risk screening for older adults. Therefore, the purpose of our study is to evaluate the effect of a 10-week Square-Stepping Exercise (SSE) program in older adults using the Biodex balance system.

Methodology

Study Design

This study evaluated the effect of a 10-week Square-Stepping Exercise (SSE) program in older adults using a Biodex Balance System to quantitatively assess improvements in balance and decrease the risk of falls in an elderly population. This study took the form of a one group pretest-posttest design. There was no control group so every participant engaged in the intervention. Outcome measurements were Timed Up and Go Test, the 30-Second Chair Stand Test, the Activities-specific Balance Confidence (ABC) Scale, Biodex Fall Risk Test, and Biodex Limits of Stability Test. The Institutional Review Board of Cedarville University approved the research protocol, and all study participants gave informed consent prior to beginning the study.

Participants

This study was restricted to older adults over the age of 60 and specifically recruited from the Senior Jackets exercise program at Cedarville University, a program that takes place twice a

week where older adults exercise independently, with a student helper, or in group classes. Recruitment for this study was by word of mouth and community posters. All subjects participated in the Square-Stepping Exercise (SSE) program and pre- and post-program testing. Eleven older adults participated in the study (0 males, 11 females).

Procedures

The program was held twice a week (Tuesdays and Thursdays) for one-hour sessions, and took place in the aerobic room in the fitness center at Cedarville University. Each session included a five minute dynamic warm up, a 35 to 40 minute square-stepping workout, and a five minute cool-down involving static stretches for the lower extremities. Prior to the intervention, the participants were tested using a series of objective tests and a questionnaire to evaluate balance. The tests conducted prior to the 10-week intervention were the participant's baseline data. Participants completed a Modified Baecke Questionnaire for Elderly (MBQE), which assessed their activity level. The participants body weight and height were measured by the researchers. After the intervention, each participant was tested again and the new data was compared to their baseline data.

Intervention

The Square-Stepping Exercise (SSE) program involved a series of forward, backward, lateral, and diagonal steps on a mat with 40 squares; each square was 10 inches by 10 inches. Participants were asked to complete each pattern at a comfortable pace, and to walk on the balls of their feet with their heels off the mat. There were six different levels of square-stepping used; junior, basic, semi-regular, regular, senior, and master or challenge. Over 35 different patterns were used. The patterns were adapted from Dr. Shigematsu, creator of SSE (2008). The

complexity of the patterns increased progressively as the weeks went on. Each participant had to successfully complete each pattern three to five times before moving on to the next pattern. Each week, two to three new, more complex patterns were introduced.

The participants were deemed compliant if they attended 75% of the sessions (15 out of the 20 sessions offered). A makeup session was added in the last week to allow the participants to reach 75% completion, if needed. Participants were allowed to continue with their regular exercise activities throughout the ten weeks.

Outcome Measures

All testing occurred in the exercise science lab at Cedarville University. The first test used was the Timed-Up-and-Go test (TUG). The Timed-Up-and-Go test required the subject to start from a seated position in an armless chair, stand up and then walk three meters around a cone and return to the seated position. Each subject was instructed to complete this task as quickly as possible without running. A practice trial was used to familiarize each participant with the test. Three trials were recorded per subject. Time to complete the task was recorded in seconds. The best trial was used for statistical analysis. Time started once the subject left the chair and continued until the second contact with the chair occured (University of Nebraska Medical Center, n.d.).

The second test conducted was the 30-Second Chair Stand Test. This test assessed lower extremity strength and balance as the participants were asked to stand up from a chair as many times as possible within thirty seconds. They were instructed to sit in the middle of the chair with their hands crossed against their chest with both feet flat on the floor, and with their back straight. Time began once the subject left the chair and ceased after thirty second. The amount of

times the subjects stood up and sat back down were recorded (Centers for Disease Control and Prevention, n.d.).

The Activities-specific Balance Confidence (ABC) Scale was given prior to intervention and post intervention as well. This consists of a list of activities, and for each activity the participants are supposed to indicate their level of confidence in doing the activity without losing their balance or becoming unsteady from choosing one of the percentage points on the scale from 0% to 100%. If they do not currently do the activity in question, they must try and imagine how confident they would be if they had to do the activity (Drayer Physical Therapy Institute, n.d.).

Each subject then performed two tests on the Biodex Balance System. The system assessed each participant's neuromuscular control in a closed-chain, multi-plane test. The surface stability ranges from 1-12; 1 being least stable, and 12 being most stable. Each subject maintained a bilateral, shoulder-width stance for both tests (Biodex Medical Systems, 2012).

The first test was the Fall Risk Test (Biodex Medical Systems, 2012). This test identified potential fall candidates. During this test 20-second test, the platform changed from stable (12) to less (8) stable. The Biodex recorded the participant's postural stability as the platform shifted. Three 20-second trials were conducted per participant. The participants ability to maintain their body posture was measured. And a stability index was provided.

The second test was the Limits of Stability Test (Biodex Medical Systems, 2012). This test involved the participants moving and controlling their center of gravity within their base of support. The participants shifted their weight to control a cursor on the screen. The goal was to move the cursor to each blinking target as fast and controlled as possible. There were nine different targets that blinked in a random order. The system timed how long it took the

participant to hit each of the blinking targets. The cursor had to be held on the target for a quarter of a second for the next target to blink. Three trials were recorded for each subject. The platform setting was static. Data was recorded from each test, but the best trial was used. An overall stability was produced, as well as 8 different directions. These directions include Front, Back, Left, Right, Front Left, Front Right, Back Left, and Back Right.

Statistical Analysis

Means and standard deviations were calculated for demographic information. Changes in scores between initial testing and final testing for the balance tests, physical function tests, and ABC scale were assessed with repeated measures ANOVA. Statistical analysis was performed using SPSS software (version 24). The p value for significance testing was set at 0.05.

Results

At the beginning of the study there were 12 participants. One participant withdrew from the study due to medical problems. The average attendance rate between the participants was 85%. There was a mean age of 76 years old. The average BMI was 30. 8 kg/m^2. According to the MBQE, their activity level was scored as low to moderate. Only one of the participants had indicated falling twice during the year. The study revealed that significant differences were found for the functional fitness tests. SPSS indicated a significant difference in improvement from pretest to posttest for the Timed-Up-and-Go Test (P = .003) as well as the 30-Second Chair Stand Test (P = .043). For the Limits of Stability test, there was no significant change from pretest to posttest for the overall (P =0.162) or any of the 8 directions. The Fall Risk Test score also showed no significant change (P =0.831). The ABC scale test did not show significant improvement either (P = 0.995).

Discussion

The results aimed to examine the effects of balance training on the functional fitness, balance, and confidence of older adults. Overall, the results showed that the participants significantly benefited from the training program in areas of functional fitness. Unfortunately, there was no significant improvement with the Biodex balance system's Fall Risk Test or Limits of Stability Test. There is a possibility that this occurred due to the fact that the participants already had good balance as they were well below the normative data. It could also be because the training was not specific enough for improvements in the Fall Risk and Limits of Stability tests. Also, the Fall Risk Test may not have been challenging enough to see significant improvements.

Participants grew more confident as the program progressed. At the end of the study, participants were able to complete complex nine-step patterns with ease. While at the beginning of the study, only simple two-step patterns were used. Several participants subjectively reported to feel more "secure" at home and and in their surroundings during their post-study testing. They felt more confident in their everyday living and tasks. One participant testified that they were able to catch themselves at home and prevent a serious fall during the study. Where as the year before, they reported to having fallen three times.

Limitations of the study include the small number of participants and the lack of male participation. Therefore, the results may not be generalized to the older adults population as a whole . It is important that this topic continues to be explored in the future. A study should be conducted that continues to use objective measures of balance with a large sample size, and a more intensive program (three times a week).

There is a great need for some type of balance training intervention among older adults. Square-stepping exercise has potential to be just as if not more effective as other strength and balance programs. However, SSE is a new, cheap, feasible type of balance training. Hopefully by quantitatively measuring the effectiveness of Square-Stepping Exercise and showing significant improvements in functional fitness it becomes a more popular way of balance training. SSE provides a balance training program that is fun, effective, and easy to incorporate in fitness centers and senior living facilities around the United States.

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