Efficacy of a Mobile Application for Improving Gait Performance in Community-Dwelling Older Adults

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EFFICACY OF A MOBILE APPLICATION FOR IMPROVING GAIT PERFORMANCE IN COMMUNITY-DWELLING OLDER ADULTS

A Thesis
Presented to
The Faculty of the School of Kinesiology, Recreation & Sport
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Master of Science

By
Dustin Glenn Falls

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EFFICACY OF A MOBILE APPLICATION FOR IMPROVING GAIT PERFORMANCE IN COMMUNITY-DWELLING OLDER ADULTS

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This thesis was possible only through the will of God. My spiritual journey occurring during my studies has provided a personal testimony that is sure to inspire others in the future. I dedicate this thesis to multiple individuals that have paved the way for my success. My dedication begins with my parents, Wayne Falls and Edith Brown, who helped build the foundation for who I am today. Secondly, my best friend, who helped polish the way I internalized my own feelings, and increased my confidence in my abilities, throughout the years of my graduate studies. In addition, my dedication must include faculty and friends within the WKU KRS program. Without their guidance and support, I would have struggled to complete the program and this thesis. Furthermore, if not for Dr. Scott Lyons, my professional career would not have included this experience at WKU. His support and reference to include me in new research was the catalyst for finishing this program. Lastly, this dedication would not be complete without adding my mentor, Dr. Jason Crandall. I am in debt to his guidance, inspiration and support while earning the Master of Science in Kinesiology.
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The United States is a rapidly aging nation. Older adults have higher rates of falls than any other age group. One in four older adults fall each year. Many of these falls are associated with sedentary lifestyles and decreased muscular strength effecting balance and gait performance. Physical activity (exercise) can reduce the risk of falls among older adults, yet adherence remains low. Exergames can increase adherence to interventions that promote health and physical activity. Social engagement can increase self-efficacy and motivation to exercise. By design, the Bingocize® health promotion mobile application (app) increases social engagement, while providing a multi-factorial fall prevention intervention. The purpose of this investigation was to evaluate the efficacy of the app to improve gait in community-dwelling older adults (N=38; mean age 72.42 years ±12.58). Participants were clustered and randomly assigned to (a) experimental (n=20; using app with bingo game, health education and exercise) or (b) control (n=18; using app with bingo game, health education without exercise) condition. Each group completed a ten-week intervention that consisted of two- 45-60 minute sessions per week. Pre and post gait analysis, at self-selected (SS) and fast-walking speeds, measured using the GAITRite® Electronic Walkway (GWS). Gait analysis included parameters of velocity, cadence, step time, step length and width, and single and double support time. A mixed-model ANOVA (p < .05) was used for statistical analysis. There were no main effects observed. Significant interactions (group x time) were observed at fast speed and SS speed
compared to the control group. Significant interactions were observed at fast speed included velocity ($\lambda = .886$, $F (1, 36) = 4.61$, $p = .039$, $\eta^2_p = .114$); and step length ($\lambda = .864$, $F (1, 36) = 5.64$, $p = .023$, $\eta^2_p = .136$); and were observed at SS speed for single support time ($\lambda = .887$, $F (1, 36) = 4.59$, $p = .039$, $\eta^2_p = .113$). Post hoc analyses using paired and independent samples t-tests were conducted on gait variables with observed significant interactions. The independent samples t-test for Single Support Time (SS) post was significant ($t (36) = 2.454$, $p = .019$, two-tailed). None of the remaining post hoc analyses were significant. There was a meaningful detectable change (MDC) in mean velocity (>5 cm/s) over time, for both SS and fast walking speeds, within the experimental condition. MDC in gait speed ranges from 5 cm/s (small) to 10 cm/s (large). As for clinical significance, this should be considered a small, yet meaningful detectable change. It is the conclusion of the investigators, that the app, with the exercise intervention, can effectively produce a meaningful change in gait speed (5 cm/s), which has the potential for reducing the risk of falls in older adults. This investigation was funded by The Retirement Research Foundation.
Chapter 1: Introduction

The United States (US) is a rapidly aging and mostly sedentary nation (Centers for Disease Control and Prevention [CDC], 2013b). Following the Millennials generation, the Baby Boomers are the largest population group in America. In 2030, all Baby Boomers will be over the age of 65 (an older adult), and are expected to represent nearly 19% of the nation’s population (CDC, 2013b; Ortman, Velkoff, & Hogan, 2014). Older adults have the highest risk of falling. Researchers have reported that one in four older adults fall each year (Bergen, Stevens, & Burns, 2016). Health-related consequences from falls such as bone fractures, traumatic brain injuries, and increased fear of falling may result in decreased mobility and loss of independence (Barbour et al., 2013; Rubenstein, & Josephon, 2006). Physical inactivity and poor self-management of chronic conditions can increase fall risks in older adults.

Sedentary lifestyles can negatively affect muscle strength and health status, which can effect motor performance resulting in alterations to the gait cycle. The complete gait cycle includes specific temporal and spatial parameters that influence overall motor performance. Slower gait speed (velocity) is a motor performance measure that has been associated with falls in older adults (Van Kan et al., 2009; Verghese et al., 2009; Verghese, Holtzer, Lipton, & Wang, 2009; Viccaro, Perera, & Studenski, 2011; Wang et al., 2015). Verghese and colleagues (2009) stated that for every 10 cm/s reduction in gait speed there is approximately a 7% increase risk in falling. Middleton, Fritz, and Lusardi (2015) referenced the “Functional Vital Sign”, or walking (gait) speed, to be a predictive measure of functional decline, future health status, and mortality. The basis of this knowledge is conceptually important for understanding how to slow, or reverse, the decrease in gait
speed associated with aging. Negative alterations to the gait cycle (e.g., decreased velocity and step length; increased step width and double support time) have been suggested to predict risk of falls within community-dwelling older adults (Bilney, Morris, & Webster, 2003; Brach, Studenski, Perera, VanSwearingen, & Newman, 2007; Guralnik et al., 2000; Hausdorf, Rios, & Edelberg, 2001; Wang et al., 2015). There is, therefore, a need to improve gait performance among older adults to reduce the risk of falling.

Researchers have confirmed that exercise can help maintain functional performance needed for activities of daily living (ADL), and decrease fall risks among older adults (Sherrington et al., 2008). Multi-factorial fall prevention programs that include health education, coupled with specific exercise to reduce the risk of falling, appear promising for older adults falls prevention. (Lee et al., 2013; Shumway-Cook, Gruber, Baldwin, & Liao, 1997). Researchers have shown that exergames can increase exercise adherence (Warburton et al., 2007). Digital exergames can improve intrinsic factors influencing self-efficacy by providing reinforcement of behaviors (knowledge and performance) during game play (Thompson, 2012; Cheon, Chung & Lee, 2015). Bingocize® is an evidence-based fall prevention exergame designed to increase exercise and improve health knowledge, while playing the familiar game of bingo. The game of bingo was included to enhance social engagement and adherence to exercise (Crandall, Anderson, & Fairman, 2013). Adherence to physical activity (PA) is critical among older adults, and social engagement can increase motivation for participation. To our knowledge, no evidence-based multi-factorial programs are available within an exergame environment. Therefore, a need is present for evidence-based programs that motivate older adults to increase exercise adherence to prevent future falls.
Recently the Bingocize® health promotion mobile application (app) was developed, that combined the previous paper-based versions of the exergame into a digital version, and now playable on handheld mobile devices such as tablets. The app provides users a unique multi-factorial, digital gaming experience that includes bingo, health education and exercise. In a previous investigation using the app, adherence rates were high and participants increased functional performance (Crandall, & Shake, 2016). Researchers have yet to explore the digital analysis of gait performance from participants using the app. There is, therefore, a need to explore the efficacy of the app to enhance gait performance among community-dwelling older adults.

**Problem statement**

Despite recommendations for PA, (American College of Sports Medicine [ACSM], 2013) older adults remain physically inactive. Researchers report that low self-efficacy (McAuley, Szabo, Gothe, & Olson, 2011) and the lack of motivation (Biedenweg et al., 2014) are intrinsic factors that limit PA among older adults. As a result, older adult sedentary lifestyles increase, which can negatively affect gait performance (slower gait speed), thus increasing the risk for falling.

**Statement of purpose**

The purpose of this investigation was to determine if community-dwelling older adults using the Bingocize® health promotion mobile application (app) with exercise would significantly improve gait performance (e.g., velocity, cadence, step time, step length and width, and single and double support time) and potentially reduce the risk of falling.
Hypothesis

Participants utilizing the Bingocize® health promotion mobile app including exercise will demonstrate significant improvements in gait performance, as compared to participants in the non-exercise version.

Delimitations

1. Participants included men and women 60 years and older.
2. A diverse population of participants from multiple facilities in two separate geographic areas were included.
3. Participants included those that were able to ambulate safely independently (not wheelchair or bed bound; assisted devices were acceptable).
4. Participants with no known severe neurological disorders (e.g., Alzheimer’s, Parkinson’s, and dementia) were included.
5. Participants with a score of ≥17 on the Telephone Mini-Mental State Exam (T-MMSE) were included.
6. Participants with no known significant heart-related health concerns (e.g., congestive heart failure) were included.
7. Only participants with English as native language were included.
8. Only participants with the ability to see (digital app text on tablets) with or without glasses were included.
9. Participants were not to participate in concurrent health education or structured PA programs six months prior to the beginning of the investigation.
10. Participants were discouraged from participating in concurrent PA program during the investigation.
11. All Service Coordinators completed a formal Bingocize® training course prior to leading a session.

12. The amount of resistance training within the program was limited to two days per week, with at least 48 hours of rest between sessions.

**Limitations**

1. This investigation did not include the evaluation of Falls Self-Efficacy. This intrinsic factor could have affected results.

2. Participants received payment for their participation during this investigation. While the payment was nominal, this could have affected motivation and adherence.

3. This investigation did not include nutrition monitoring by participants. Nutrition could have played a role in the effects of learning and motor development during this investigation.

4. Participants were discouraged from participating in PA outside this investigation, but this was neither tracked nor enforced.

5. A different Bingocize® certified instructor led each cluster of participants.

6. The length of the intervention was ten weeks. A longer intervention period might have produced significant main effects in gait performance for the experimental condition.

7. Motivation levels may have varied between individuals – these were not evaluated.

8. Participants may or may not have enjoyed the game of bingo.

**Operational Definition of Terms**

- **Aerobic fitness**: The availability and ability to utilize oxygen to meet the needs of aerobic metabolism during bodily movements.
• Adherence (to exercise program): how frequent participants are present during programs.

• Attrition (from exercise program): participants that start but fail to complete the program; quit.

• Baby Boomer: a person born between 1946 and 1964.

• Bingocize®: an evidence-based PA program that combines exercise with the game of bingo.

• Cadence: the total number of steps per minute during the gait cycle.

• Double Support: a period of time within the gait cycle when an individual is supported by both legs – this is also the stance phase of gait.

• Exergame: a game that combines exercise during gameplay.

• Gait: an individual’s manner of walking that includes the combination of stance and swing phases for each leg.

• Gait cycle: complete execution of all stance and swing phases of gait.

• Gait Velocity: the speed of an individual’s gait in a given direction.

• Multiple Chronic Diseases or Conditions (MCDC): having two or more chronic diseases or conditions.

• Older adult: a person age 65 and over; a senior.

• Physiological function (performance): a special action of an organ or body part such as balance, coordination, strength, power, and range of motion.

• Resistance training: exercise that use an external load (weight) to help increase muscular strength, endurance, power, and size.

• Sarcopenia: the natural loss of muscle tissue due to the aging process.
• **Serious Game**: a game designed where entertainment is not the focus of gameplay.

• **Service Coordinator**: staff, located at the facilities included in this investigation, that are responsible for providing assistance in the form of information and health promotion activities to the residents.

• **Single Support**: a period of time within the gait cycle when an individual is supported by a single leg – this is also the swing phase of gait.

• **Step length**: the length measured from the heel center of one foot (current step) to the heel center from the previous foot fall of the opposing foot.

• **Step width**: the length measured between midpoint of one foot to the midpoint of the opposing foot.

• **Structured Exercise**: Preplanned PA followed precisely to illicit a specific health or fitness-related goal.

• **U.S. Guidelines for Physical Activity**: a minimum of 150 minutes of planned structured PA each week that includes aerobic fitness, resistance training, and flexibility (balance for senior adults).

**Summary**

In 2029, the last Baby Boomer will reach old age (over 65). Now being second to only the Millennial’s, this generation is the largest population group. As this group approaches old age, health professionals and researchers should focus on ways to improve motor function and gait performance, decrease the rate of chronic diseases and conditions, and improve overall quality of life. Too many older adults receive fatal injuries from falls each year. Many of these falls are preventable with certain lifestyle modifications and increased levels of PA. Physical activity remains low in this population group despite
public health awareness efforts for promoting daily activity. There is, therefore, a need for programs that not only provide PA for older adults, but also motivates them to participate and be more active. Bingocize® is health promotion program designed to motivate older adults to increase PA, while playing the game of bingo. The design of this investigation was to compare the effects of two versions of the Bingocize® health promotion mobile app: (1) exercise, bingo and health education; and (2) bingo and health education. The aim of this investigation was to determine if community-dwelling older adults using the Bingocize® health promotion mobile app with exercise would significantly improve gait performance for potentially reducing the risk of falling.
Chapter 2: Review of Literature

An Aging Population

The US is a rapidly aging nation. The future shift in population demographic is largely due to the “Baby Boomer” generation aging into late adulthood (65 and over). By 2030, when all Baby Boomers are over 65, the older adult population will likely represent approximately 19% of the total population of the US (CDC, 2013b; Ortman, Velkoff, & Hogan, 2014). Furthermore, older adults are now living longer lives, but with lower quality of health. Over 90% of older adults are living with at least one chronic disease or condition, and over 68% of Medicare beneficiaries have at least two (Lochner, 2013). As the Baby Boomer generation continues to increase in age, the incidence rates of older adults with multiple chronic diseases and conditions (MCDC), and the health care expenditures, will increase as well. According to the Congressional Budget Office (CBO) and Medicare, spending may reach over $1 trillion by 2025 (CBO, 2015). There is a need for drastic measures to improve the well-being of older adults; this steady demographic shift in the US population age will have a profoundly negative effect on the overall health and financial status of the nation.

Chronic diseases and conditions significantly diminish the overall quality of life. More likely to be affected by disability are older adults, who are at greater risk of developing MCDC and, therefore, are more likely affected by disability (US Department of Health and Human Services [USDHHS], 2010). Older adults, especially those living with MCDC, will experience increased rates of disability due to health-related factors such as fatigue, muscle weakness and pain. This increase in disability will directly affect the functional abilities of
older adults causing a decrease in ADLs, and potentially lowering the amount of daily PA (CDC, 2013a).

Older adults’ lifestyles are typically more sedentary compared to younger adults (Ward, Clarke, Nugent, & Schiller, 2016). Less than half of US adults (age 18 and over), participate in regular leisure-time PA. In addition to decreased movement, older adults have the highest rates of doctor-diagnosed arthritis. Over 20 million US adults report limiting activities due to arthritis (CDC, 2013c). Additionally, individuals with arthritis are more susceptible to falls due to decreased physical movement. According to the CDC (2013c), about half of all adults aged 65 and over have arthritis compared to 30% of adults between the ages of 45 and 64. This overwhelming prevalence of disability and conditions significantly affects overall PA levels. Furthermore, the rapidly aging nation will begin experiencing increased levels of sarcopenia, thus affecting the prevalence of disability and further increasing physical inactivity rates (Fielding et al., 2011). This loss of muscle mass, coupled with the increasing rate of MCDC, has the potential to increase morbidity and mortality rates. However, the loss of muscle mass and the symptoms associated with chronic diseases may decrease when following recommended levels of physical activity. Furthermore, increased physical activity helps to maintain, and potentially restore, functional capacity influencing gait performance in older adults. (ACSM, 1998).

Physical Activity Recommendations

Physical activity performed on a routine basis has been shown to simultaneously increase muscular strength and endurance, improve motor function, enhance balance and stability, and improve gait speed; thus reducing the risks for falling and decreasing the symptoms of many chronic diseases in older adults (CDC, 2013a; Chodzko-Zajko, W.J. et
PA recommendations for older adults include 150 minutes (30 minutes for 5 days) PA per week of aerobic exercise, and two additional days of resistance training with at least 48 hours’ rest between resistance training days (American College of Sports Medicine [ACSM], 2013, Chodzko-Zajko et al., 2009; Nelson et al., 2007; Thompson et al., 2010; USDHHS, 2008). For better health outcomes among all ages, the ACSM suggests daily PA and further suggests that adults should begin both aerobic and resistance training early in life to create and sustain healthy habits and provide increased muscle-mass prior to sarcopenia.

As shown in the CDC, *The State of Aging and Health in America* (CDC, 2013b), less than 32% of older adults engage in the recommended daily PA. An inactive lifestyle can lead to substantial decreases in muscular strength and endurance, which can cause impaired motor function. Decreased motor function can significantly increase mortality risks in older persons, especially in association with fall risk (Bassey, 1998). Approximately 43% of all older adults met aerobic PA guidelines, and less than 16% of older adults participated in both aerobic and anaerobic training (Ward, Clarke, Nugent, & Schiller, 2016). The majority of adults rarely follow recommended PA guidelines to maintain both muscular strength and endurance, thus increasing the potential of impaired motor function and increased risk of mortality from fall-related injuries or chronic conditions. This ongoing decrease in physical activity rates and general lack of exercise adherence sets the stage for both increased rates of MCDC and unintentional injuries associated with falls.

The decline in motor function coupled with increased rates of chronic diseases increases the necessity for an effective PA program with good adherence. Adherence can be defined as the frequency an individual attends a health promotion (or PA) program.
Good adherence to PA programs may significantly increase motor function. Researchers have reported that improving motor function is likely to decrease the risk of falls (Lee, & Skerrett, 2001). One way to improve motor function, and thus reduce the risk of falling, is adhering to a PA regimen designed specifically to enhance and maintain muscular strength, power and endurance (USDHHS, 2008). Therefore, if older adults maintain adherence to PA programs, it’s likely they will experience increased motor performance, decreased prevalence of MCDC, and reduced risk of falls.

Falls among Older Adults

Older adults are at the greatest risk for falls. Each year, one in four older adults will fall (Bergen, Stevens, & Burns, 2016). There are significant health-related and fatal consequences associated with these falls such as a) bone fractures (e.g., hip and wrist); b) traumatic brain injuries; c) an altered perception of physical ability (lowered self-efficacy); d) increased fear of falling, resulting in decreased physical movement; and e) general decline in functional abilities (Barbour et al. 2013; Rubenstien, & Josephon, 2006). Additionally, the financial burden associated with falls is significant. In 2015, the annual direct medical costs associated with falls were over 30 billion dollars (Burns, Stevens, & Lee, 2016). Many unintentional fall-related injuries are preventable through risk modification; therefore, it is imperative that exercise professionals and researchers develop strategies to address key risk factors associated with falling.

Physical mobility is a key risk factor in preventing falls. In 2015, the National Council on Aging (NCOA) released the Falls Free ®: 2015 National Falls Prevention Action Plan (Cameron, Schneider, Childress, & Gilchrist, 2015). NCOA is one of the
national leaders in falls prevention, and clearly defined a vision and goal of fall prevention in the U.S. within the plan:

“Vision: Older adults will have fewer falls and fall-related injuries, maximizing their independence and quality of life.

Goal: To implement a National Action Plan with specific goals and strategies to effect sustained initiatives that reduce falls among older adults.” (p.5).

The plan addresses key fall prevention risk factors (i.e., Physical Mobility, Medications Management, Home Safety, and Environmental Safety). By addressing each risk factor, multiple goals, strategies, and action plans were developed to reduce the incidence of falls. Essentially, the foundation of this goal is to increase education, awareness of fall risks, and access to and participation in evidence-based interventions for older adults. In addition, the vision is to increase PA levels to improve muscular strength and endurance to decrease physical-related fall risks associated with aging. Additionally, NCOA suggested that public health messaging reference positive healthy living and wellness. However, the emphasis of the message and promotion of increased PA levels should focus on independent living and less on reducing or preventing falls. The plan includes multiple action steps for improving physical mobility. Essential components of the plan include reaching specific audiences (e.g., Baby Boomers, culturally diverse populations). Utilizing the Stopping Elderly Accidents, Deaths and Injuries (STEADI) toolkit for assessing fall risks. Promoting PA and empowering older adults to participate in activities to reduce falls such as enhancing muscle strength and conditioning, and health education. In addition, applying a person-centered approach to evaluate readiness of change (behavior
modification) and providing referrals for those in the contemplation stage of the transtheoretical model (Kaniewski, Stevens, Parker, & Lee, 2015). By following the NCOA plan, professionals can make informed decisions to help reduce the prevalence of falls among older adults. This investigation was a unique method of using many of the elements from the NCOA plan. The evidence-based intervention used aligns with the NCOA plan by promoting physical activity and increasing health knowledge intended for reducing fall rates among older adults.

Higher fall rates also correlate with higher prevalence of arthritis in older adults (Barbour et al., 2013). Older adults have the highest rates of arthritis and are more sedentary compared with any other age group. Moreover, a sedentary lifestyle significantly effects the rates of MCDC within older adult populations, and therefore directly correlate with an increased risk of falling. Health-related factors, such as arthritis, can limit range of motion and increase pain, thus creating motor disabilities that can affect everyday motor performance such as walking.

While walking is typically a normal automatic task for younger adults, older adults require more attention to prevent falls. Decreased motor control, a component of executive function, may be a significant reason for decreased functional performance and associated with impaired cognitive processes. This decrease in motor performance can cause alterations in gait speed, velocity, and step length, width and time. Some researchers suggest that alterations in motor performance often create significant gait variability, thus increasing the risk of falling among older adults (Hausdorff, Rios, & Edelberg, 2001). Hausdorff and colleagues reported an association between increased gait variability and a
history of falls in community-dwelling older adults. There is, therefore, a need to improve gait performance to reduce the risk of falls among older adults.

*Gait Performance in Older Adults*

Many researchers and clinicians utilize the analysis of gait performance to explore the relationships between gait parameters and falls. The analysis of gait parameters includes temporal (e.g., speed, stride velocity, cadence, single and double support time) and spatial (e.g., base of support, step length and width, stride length and width) measurements. A reduction in gait speed is a potential performance indicator associated with increased fall risk (Campbell, Borrie, Spears, 1989; Luukinen, Koski, Laippala, & Kivela, 1995; Van Kan et al., 2009; Verghese, Holtzer, Lipton, & Wang, 2009; Viccaro, Perera, & Studenski, 2011; Wang et al., 2015; Wolfson, Whipple, Amerman, & Tobin, 1990).

Verghese and colleagues stated that for every 10 cm/s reduction in gait speed there is approximately a 7% increase risk in falling. Middleton, Fritz, and Lusardi (2015) suggested that clinicians should utilize walking (gait) speed (or the “functional vital sign”) as a predictive measure for functional decline, health status, and risk of mortality. This is conceptually important for understanding how to slow or potentially reverse the decrease in gait speed associated with aging. Negative alterations to the gait cycle (e.g., decreased velocity and step length; increased step width and double support time) have been suggested to predict future risk of falls within community-dwelling older adults (Bilney, Morris, & Webster, 2003; Brach, Studenski, Perera, VanSwearingen, & Newman, 2007; Guralnik et al., 2000; Hausdorff, Rios, & Edelberg, 2001; Wang et al., 2015). The influence
of altered gait speed appears to be the most commonly suggested measure for detecting meaningful change.

Perera and colleagues (2006), conducted a secondary data analysis from previous studies to estimate the degree of meaningful changes in gait speed, and what might be suggested as a clinically significant change. The researchers suggested that estimated small meaningful changes in gait speed fell between the ranges of 4 cm/s to 6 cm/s, and the more substantial changes fell between 8 cm/s to 14 cm/s. They further suggested that gait speed be used as a clinical measure for detecting the degree of change over time. This is clinically significant as these measurements provide a useful tool for clinicians and researchers to better predict future health status, and responsiveness to specific interventions.

In their white paper, Fritz and Lusardi (2009) further support the suggestions by Perera et al. (2006), by stating that walking speed is “almost the perfect measure” for predicting future health status. They continue by referencing that .05 m/s (or 5 cm/s) is needed for a small, yet meaningful change in gait speed. There is, therefore, a reason to consider that the degree of meaningful change observed (effect), in response to a specific intervention, may have clinical significance.

It is evident that gait speed is significant factor in predicting health status in older adults. However, gait speed is not the only factor associated with increased fall risk. It has been reported that variability in gait is a significant factor for increased fall risk (Callisaya et al., 2010). In 2010, Callisaya and colleagues reported on the relationships between the levels of variability in each individual’s gait in association to fall risks. They believed that the variability was weighted more than average gait speed and stride length. Existing research supports their position (Hausdorff, 2005; Hausdorff, Rios, & Edelberg, 2001;
Maki, 1997). Considering the clinical significance, there appears to be a need for more research in the area of gait performance, and overall variability to determine the best approach to reducing the risk of falls. A variety of fall prevention interventions, and their impact on gait performance, have been explored. Researchers suggest that the best approach for decreasing fall risks is multi-faceted (a.k.a., “factorial and dimensional”) exercise programming designed to improve balance and mobility skills (Shumway-Cook, Gruber, Baldwin, & Liao, 1997).

Multi-dimensional exercise interventions include a combination of exercises to address muscular strength and endurance, balance, flexibility, cognition, and motor performance during the gait cycle. Interventions should purposely increase motor performance and decrease variability during the normal walking gait cycle. The gait cycle encompasses multiple muscle groups to control the consistent movement of the whole-body center of mass. During normal walking, the cycle includes single and double leg support phases. Each cycle consists of two-step phases (that include leg swings) with each leg; these steps include two single and double support phases. Walking is an absolute key ADL among community-dwelling older adults, and improving gait performance may help increase walking frequency and safety, and critical in preventing falls.

There is a pressing need for multi-dimensional exercise interventions that can improve motor performance and, potentially decrease the risk of falling for this population. Unfortunately, adherence to exercise programs remains low among older adults.

*Barriers to Exercise Adherence*

Many barriers can impede exercise adherence among older adults. Researchers have reported the following barriers to exercise adherence. Generally poor health
conditions, leaving individuals feeling weak and fatigued making it difficult to participate. Chronic pain associated with many diseases and conditions can affect participation. The fear of injury, especially related to falls, can prevent an individual from joining exercise programs. Environmental safety concerns, such as terrain, lightning, and or specific location, can prevent older adults from attending a program. The length of an exercise program can influence the desire to participate. Frequency of exercise in the program can cause increased fatigue, pain or weakness; thus, decreasing interest in further participation. The lack of a physician’s recommendation for exercise programming can prevent many older adults from attending a new program. Many older adults will follow the direction of their health provider, if a recommendation is given (Kerse, Elley, Robinson, & Arroll, 2005). Limited knowledge of exercise techniques and the benefits associated with adherence is common in older adults. Increasing this knowledge may increase adherence. Unhealthy habits sustained throughout adulthood can persist. Changing habits to incorporate new healthy ones often requires specific self-management skills. Older adults perceive exercise as therapy or medicine and not for recreation only. These perceptions can prevent adherence to exercise programming (Chase, 2011; Schutzer, & Graves, 2004).

As people age they become aware of their physical limitations due to functional decline. This knowledge can decrease an individual’s self-efficacy in their personal ability to be physically active (Bandura, 1997; McAuley, Szabo, Gothe, & Olson, 2011). Self-efficacy is a personal feeling or belief in the capability to accomplish a specific action or outcome. It has been suggested that self-efficacy decreases with age (Jancey, Lee, Howat, Clarke, Wang, Shilton, 2007; Resnick, Palmer, Jenkins, & Spelling, 2000). Decreased self-efficacy can cause older adults to decrease exercise adherence. Despite the obvious
barriers, researchers have discussed strategies for increasing exercise adherence among older adults.

Previous researchers found exercise adherence increases when offered within a safe and supportive environment (King, 2001). This may be due to the increased socialization experienced within groups (Bopp et al., 2009). By increasing socialization, older adults feel more engaged and supported. This social interaction is the premise behind the Social-Cognitive Theory (SCT) (Bandura, 1986). According to Bandura (1986), the SCT is a combination of all dynamic factors associated with self-efficacy. Bandura (1986) suggested these factors included inner-personal (motivation), behavioral (avoidance), and environmental (safety). This theory supports the concept that neither interpersonal motivation nor external factors are solely the driving mechanism for change in individuals, but rather a combination of all factors and not in given or equal amounts. King et al. (1992) suggested that three categories influence exercise adherence: 1) intrinsic factors; 2) environmental factors, including both the program site and social interactions, 3) and program specificity, including the type of exercises and modalities (Jancey et al., 2007). When designing an exercise program for older adults, all determinants of the SCT, and the suggestions made by King et al. (1992) should be considered. The lack of intentional exercise program development could result in decreased self-efficacy resulting in fluctuations in program adherence. An exercise program should a) be rewarding and build on previous success; b) be effective at safely improving health, which includes both the exercise movement and environment; and c) be socially engaging and enjoyable.

Socially engaging evidence-based PA programs designed for older adults have been effective at increasing exercise adherence and improving health-related outcomes.
However, only an estimated 15% of older adults are participating in regular evidence-based PA programs (CDC, 2011; Resnick, 2001). Additionally, the World Health Organization (WHO) reported adherence is low for therapeutic treatments (e.g., medication, nutrition and exercise) for chronic diseases. Roughly, half of chronic disease patients adhere to prescribed treatments (WHO, 2011). Despite public health approaches to improve adherence to health promoting programs, attendance remains low and is suggested to be a significant barrier to improving the overall health and quality of life for older adults (Conn, Minor, Burks, Rantz, & Pomeroy, 2003).

Barriers to exercise adherence, coupled with the increasing population of sedentary older adults, will likely increase the number of reported injuries and illnesses. After conducting a systematic review of the literature, Ezzat, Macpherson, Leese, & Li (2015) found a limited number of interventions focused on exercise adherence suggesting future development of exercise programs should focus on exercise adherence. Increasing adherence rates has the potential to improve the validity of research and help create sustainable health benefits for older adults participating in evidence-based exercise programs.

There are multiple methods of increasing exercise participation including social support and the incorporation of games. There is evidence social support can motivate older adults to participate in exercise (Costello, Kafchinski, Vrazel & Sullivan, 2011; Heisler, 2007; Tomlin, & Asimakopoulou, 2014). Furthermore, games provide an enjoyable experience for participants, and when combined with exercise (an exergame), can provide meaningful increases in exercise adherence. The concept of adding exercise to a fun game environment may increase self-efficacy and motivation. Exergaming is a method that can
increase exercise adherence in older adults, and therefore there is a need for further exploration among researchers and exercise professionals.

**Exergaming**

An exergame is a potential method for behavior modification in older adults. The social cognitive theory (SCT) provides a base for developing a comprehensive model for exploring behavioral change in video games (Baranowski, T., Buday, Thompson & Baranowski, J., 2008). This comprehensive model includes the steps of attention, retention, production and motivation. These steps are relational to both social and physical environments. The SCT is suggestive to how people acquire new behaviors. One such behavior related to falls prevention, increased confidence, and motivation for physical movement, is self-efficacy (Bandura, 1986). The idea of combining exergames with health education (“serious games”) has emerged to improve self-efficacy using a fun yet “serious” method (Cheon, Chung & Lee, 2015; Thompson, 2012). A player’s attention is important for maintaining focus in the process of SCT. Immersion into the story or gameplay (e.g., bingo) is important for assisting with attention, but may not help with behavior change. Retention is strongly linked with positive emotions (e.g., winning a game of bingo), which is also linked with memory (Baranowski, T., Buday, Thompson & Baranowski, J., 2008; Thomas & Hasher, 2006). Intrinsic motivation is the final piece of the model’s design. An association appears to exist between enjoyable experiences and increased performance and adherence. Motivation can also be influenced by a positive social experience (e.g., playing a game with friends) that can increase self-efficacy.

Interests in exergaming research has significantly increased over the past decade. In 1997, Annesi and Mazas (1997) used exercise bikes equipped with virtual reality (VR)
equipment attached. Divided into groups, Forty-five clients from a fitness center used either VR exercise bikes or traditional upright and or recumbent exercise bikes. They reported that the participants that used VR exercise bikes had better adherence and attendance than compared to traditional exercise bikes. However, the reasons, or factors, why this occurred were unknown. Regardless, the researchers reported using these devices to motivate may increase exercise adherence. Bogust (2005) explored the history of exergaming to determine how these games motivate players to be physically active. In the review, Bogust was concerned with psychological effects rather than the physiological effects of exergames. Additionally, he suggested that many games promoted physical activity and motivation to be active, yet there was still a general desire to increase sedentary time due to environmental and psychological factors.

Exergaming is not limited to just home-based consoles or fitness equipment equipped with a video game. Exergames, designed for mobile devices, are available on high-powered phones, tablets and laptops. The advent of mobile exergames is promising since the user can now play the game virtually anywhere. Wylie and Coulton (2008) divided exergaming into two main groups, games that require an exercise input device and those using a particular type or generic game to encourage physical movement. They presented a game titled Health Defender that utilized mobile phones as a platform for exergaming. The game used heart rate and physical movement (real-time physiological data) to control the player within an environment. This idea of using real-time physiological data for games aids the exergaming phenomenon by providing a way to both monitor and maximize health benefits by using a player-based virtual environment. The
researchers concluded that it is critical to establish a link between physical activity and game play in order to create a successful exergame.

Regardless of which platform is used, exergames can increase exercise adherence. The design of the game itself is the most critical. The game must be safe and effective for improving physiological functions, while providing a sense of enjoyable entertainment. Sinclair, Hingston, Masek and Nosaka (2009) provided an “exergaming system model”, designed to establish a better understanding of the framework for exergame development. They suggested use of this model for successful exergame design. This model consists of five central components (game software, audio/video feedback devices, human player, exergame control device, and biosensors). If a developer is creating an exergame based on player movement, then this model, based-mostly on biofeedback from physiological responses, appears to be a valid approach. However, player movement (biofeedback) is not included in all exergames. Exergames can simply be the combination of a traditional game that incorporates exercise into game play. This type of exergaming provides an easier method for game development, since testing software and monitoring biofeedback is non-essential. It is important for researchers and practitioners to find new, cost effective strategies to include exercise into games to provide an enjoyable experience.

There is a dire need to improve physical activity rates in the United States, and around the world. Exergames can be a successful tool for increasing exercise adherence in most age groups. As gaming technology improves, the opportunities for exergaming should increase as well. There is a need for further research to expand the knowledge regarding the psychological and physiological effects from new exergaming designs. Researchers should consider using a variety of exergaming methods, both equipment and software, to
find new ways to promote physical activity in all age categories. Specific to this investigation, the method should encourage social engagement and motivate older adults to have fun while meeting recommendations for PA.

*Bingocize®*

The Bingocize® program is a multi-dimensional exergame that motivates older adults to participate in recommended PA, structured within an enjoyable bingo game environment. The concept of this exergaming program is to enhance functional performance in older adults while offering a “fun” enjoyable experience that increases program adherence. By using bingo as a program enhancer, individuals are more interested to participate in exercise. Crandall, Fairman and Anderson (2015) reported that participants enjoyed the game of bingo in conjunction with the exercises. Overall adherence to the intervention was > 80 percent. The authors’ concluded Bingocize® delivers physical activity through an enjoyable experience for both facilitator and participant.

According to the United States Administration for Community Living, Bingocize® meets the high-tier definition for evidence-based health promotion programs. This is important when considering appropriate physical activity programs to address the national action plan for falls prevention presented by the NCOA. In light of modern technological advances in program delivery, the developers created a digital version (application or app) of the game. The app is playable on tablets, pc and smart phones. Initial testing of this app version of Bingocize® included significant improvements in program adherence and increased functional performance (Crandall, & Shake, 2016). At this point, there is a need for additional evidence to support the efficacy of program especially the ability of the Bingocize® health promotion app to improve gait performance in older adults.
Chapter 3: Materials and Methods

Design

The proposed investigation was a twelve week, cluster randomized trial (CRT). This CRT was an experimental, mixed repeated-measures (pre/post) design. The investigation included a volunteer sample of community-dwelling older adults. These individuals were recruited from independent living facilities located in Nashville, TN (n=1) and Owensboro, KY (n=3). Proximity to the university, and relationships established with management of the facilities, influenced the selection of these facilities. The minimum number of participants per group or cluster was eight; to better facilitate social interactions among the group members. Clusters were formed at each facility, and two facilities had enough participants to form an additional cluster. All clusters used the Bingocize® mobile app intervention. Clusters were randomly assigned to one of two conditions using random number generating software (SPSS Version 24): (a) experimental, that used the full version of the Bingocize® mobile app that included bingo, exercise, and health education, and (b) control, that used a version of the Bingocize® mobile app that included bingo and health education.

Participants

Participants were community-dwelling older adults aged 60 years and older. Participation criteria were: age (≥ 60), independent ambulation (e.g., not wheel-chair bound; assisted devices are acceptable), no known severe neurological disorders (e.g., Alzheimer’s, Parkinson’s, Dementia), Telephone Mini-Mental State Exam (T-MMSE) score ≥ 17, no known significant heart-related health concerns (e.g., congestive heart
failure), English as native language, and not participating in concurrent health education or physical activity programs throughout the investigation.

**Procedures**

Recruitment of participants began after acquiring approval from the Western Kentucky University (WKU) Institutional Review Board (IRB) (WKU IRB# 16-230). The investigators provided a 30-minute presentation for potential participants during a recruitment site visit at the selected facilities (n=4). These occurred between 30-60 days prior to the beginning of the intervention. During these recruitment site visits, interested participants completed the WKU-IRB informed consent document (see Appendix A), Health Assessment Questionnaire, Physical Activity Readiness Questionnaire, and Medical Release Form (adapted from the “Alamogordo Physical Therapy & Wellness Center, Health Screening Survey for Older Adults Ages 70 and Older”) (Bryant, & Green, 2005). Following the recruitment site visit, trained graduate students telephoned each interested participant to complete the T-MMSE. Participants that scored < 17 on the T-MMSE were not assessed, and excluded from the investigation.

The twelve-week investigation consisted of pre and post assessments, and ten-week delivery of the Bingocize® health promotion mobile app, within all clusters. Once eligibility was established, pre-assessments were scheduled (week one of the investigation). The investigators provided assessments at each site, on separate days. Both conditions (experimental and control) began the selected Bingocize® intervention the week immediately following pre-assessments. Both conditions participated in Bingocize® twice per week, for ten weeks (occurring during week two through eleven). After completion of the intervention, the investigators repeated the assessments at each site during week twelve.
Service Coordinators, representing each independent living facility, led the ten-week Bingocize® intervention within their serviced site. These Service Coordinators were existing staff within the independent living facilities. Their role is to provide education, resources, and recreational activities for the community-dwelling older adults. To prepare the Service Coordinators to lead the intervention, researchers provided a training workshop, prior to week one, to adequately facilitate the intervention. Researchers conducted site visits periodically during the intervention weeks to ensure fidelity of the Bingocize® mobile application. Technical assistance was available to each Service Coordinator through phone and email communication throughout the investigation.

Outcome Measures

Gait analysis was performed at baseline and post-intervention. The analysis included temporal (time) and spatial (distance) parameters. Gait performance is the fluctuation of temporal and spatial gait parameters. Temporal parameters included cadence, velocity, step time, single support time, and double support time. Spatial parameters included step length and step width. Gait measurements collected with the (GWS) (CIR Systems Inc., USA). As instructed, participants walked across the GWS carpet four separate times (trials). The gait analysis formed as tests, calculated by using gait parameter means from the four separate trials. Participants’ gait analysis included two different speeds; (1) normal self-selected (SS) walking speed (participants instructed to walk at their normal, habitual walking pace), and (2) fast walking speed (participants instructed to walk safely and fast as possible). Similar procedures effectively used in previous research to collect mean gait performance data (Wang et al., 2015). These data were transferred to a secure laptop for analysis.
Many researchers have used the GWS to analyze gait characteristics as a predictor of falls (e.g., Krishnamurthy, & Verghese, 2006; Montero-Odasso, Wells, Borrie, & Speechley 2009; Reelick, van Iersel, Kessels, & Rikkert, 2009; Verghese, Holtzer, Lipton, & Wang, 2009). Gait performance is a valid measurement to analyze seniors’ mobility and fall risk (Bridenbaugh, & Kressig, 2011). The GWS provides a good source for functional and dynamic analysis of gait parameters. The protocol for testing is fast, simple and safe. Testing began by rolling-out the GWS mat into an open, well-lit space with no fall hazards. Participants were instructed to walk across the mat, with or without preferred footwear designated by the researcher (commonly the participant’s shoe, which included a low heel). There were no devices connected to participants and they could use assisted walking devices if needed.

The GWS is a valid and reliable device to measure gait performance (Menz, Latt, Tiedemann, San Kwan, & Lord, 2004). Researchers have used the device to evaluate the risk of falls and the effectiveness of interventions to improve mobility in older adults (Eggenberger, Theill, Holenstein, Schumacher, & de Bruin, 2015). The GWS is a transportable system that provides a safe walking pathway for assessing older adult gait performance. The GWS carpet collects digital measurements of gait performance by receiving data from embedded pressure-activated sensors that identifies foot placement as individuals walk across the carpet. The sensors transfer measured data to a software application that calculates spatial and temporal parameters (Menz, Tiedeman, San Kwan, & Lord, 2003; Webster, Wittwer & Feller, 2004).

It is important for researchers to use valid assessments of gait performance when developing programs to improve motor performance associated with the gait cycle. To
measure the validity of the GWS, as compared with Clinical Stride Analyzer®, Bilney, Morris and Webster (2001) evaluated the concurrent measurements of spatial and temporal gait parameters of twenty-five adult subjects. Participants instructed to complete nine walking trials, at varied speeds. The measures of speed, cadence, and stride length demonstrated good validity and reliability in adults with normal gait.

In 2004, Menz and colleagues reported their test of GWS reliability (Menz, Latt, Tiedemann, San Kwan, & Lord, 2004). They stated that individuals could use the system to measure walking speed, cadence and step length with confidence. Based on their data, there was, however, insufficient support to test for base of support and angle measurements of toe in and out positions. These results are helpful for both clinician and researcher that desire to evaluate the effects of a specific intervention on gait performance.

Webster, Wittwer and Feller (2004) also tested the reliability of the GWS. Webster and colleagues reported that the GWS is a reliable measurement tool for assessing individual spatial and temporal gait parameters in older adults. Additionally, they reported good concurrent validity for the same measurements (walking speed, cadence, and step length) within the Menz study (2003). Van Uden and Besser (2004) re-evaluated the test-retest reliability. Their study included an evaluation of validity and reliability over time, and used interclass correlation coefficients (ICC) to evaluate the test-retest reliability. Nearly all gait parameters listed at or above 0.90 ICC. They proposed that all gait measurements included within their study indicated excellent test-retest reliability. These findings support the GWS as a reliable and valid instrument to evaluate gait measurement (spatial and temporal).
Exercise Adherence

Adherence to exercise program is essential for improving functional capacity (e.g., muscular strength, power, endurance, flexibility) associated with the gait cycle. Using attendance logs, Service Coordinators monitored overall participation during the intervention. The investigators collected these attendance logs at the end of the investigation. To better compare results between conditions, exercise adherence should be non-significant.

Anthropometrics and Other

The investigators collected height, body weight (used to calculate Body Mass Index), and resting blood pressure from all participants.

Statistical Analysis

A one-way ANOVA and Chi Square analyses were used to compare baseline characteristics of participants. Exercise adherence between conditions was compared using an independent samples t-test. The independent variable for this investigation was the condition assignment. The dependent outcome variables were the parameters associated with gait performance. Gait parameters were analyzed using descriptive and frequency analysis. Main effects, and time (pre and post) x group interactions were examined using a mixed-design ANOVA. Post hoc analyses using paired and independent samples t-test were performed for any significant interactions observed. All analyses of gait parameter data were two-tailed and conducted using the Statistical Package for the Social Sciences (SPSS Version 24). Statistical significance was set at the p < .05 level. Effect sizes, using partial eta squared (\(\eta_p^2\)), are interpreted as small (.01), medium (0.05), or large effect (0.14) (Cohen, 1988).
Chapter 4: Manuscript

A MOBILE APPLICATION FOR IMPROVING GAIT IN COMMUNITY-DWELLING OLDER ADULTS

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Abstract

Older adults are at risk of decreased functional performance due to increased sedentary behaviors and sarcopenia. This decrease in functional performance alters the gait cycle (e.g., decreased gait speed) and increases fall risks. In fact, one in four older adults fall each year. Physical activity (exercise) can improve functional performance, yet adherence remains low. Adherence to exercise interventions can improve functional and gait performances among older adults. Researchers have suggested exergaming (e.g., mobile gaming applications) as a successful method to increase adherence to interventions that promote health and physical activity. The purpose of this investigation was to evaluate the efficacy of a mobile health promotion application (app) to improve gait performance in community-dwelling older adults (N=38; age 72.42 ±12.58). Volunteers were recruited and assigned to clusters. Clusters were randomly assigned to an (a) experimental (n=20; app with exercise) or (b) control (n=18; app without exercise) condition. Each cluster completed the twelve-week protocol that consisted of pre and post gait performance assessments, and participation in the mobile app intervention. Measurements included pre and post gait analysis at self-selected (SS) and fast walking speeds using the GAITRite® Electronic Walkway. Gait analysis included parameters of velocity, cadence, step time, step length and width, and single and double support time. Statistical analysis included a mixed-model ANOVA (p < .05). There were no observable main effects. Significant interactions (group x time) were observed at fast speed and SS speed. Significant interactions at fast speed included velocity ($\lambda = .886, F(1, 36) = 4.61, p = .039, \eta_p^2 = .114$); and step length ($\lambda = .864, F(1, 36) = 5.64, p = .023, \eta_p^2 = .136$), and at SS speed included single support ($\lambda = .887, F(1, 36) = 4.59, p = .039, \eta_p^2 = .113$). Post hoc analyses revealed
that all variables were statistically non-significant. In conclusion, the app, with the exercise intervention can effectively produce a meaningful change in gait speed (5 cm/s), which has the potential for reducing the risk of falls in older adults. The Retirement Research Foundation funded this investigation.

**Key words:** intervention, exercise, gait speed, fall prevention, mobile app
Introduction

The United States (US) is a rapidly aging and mostly sedentary nation (Centers for Disease Control and Prevention (CDC), 2013a). Researchers believe by 2030, the US older adult population will represent approximately 19% of the nation’s total population (CDC, 2013b; Ortman, Velkoff, & Hogan, 2014). Older adult falls are a significant public health concern with one in four older adults, age 65 and over, falling each year (Bergen, Stevens, & Burns, 2016). Health-related consequences from falls such as bone fractures, traumatic brain injuries, and increased fear of falling may result in decreased mobility and physical activity (PA) (Barbour et al., 2013; Rubenstein, & Josephon, 2006). Sedentary lifestyles can negatively affect muscle strength and motor control resulting in alterations to the gait cycle.

The complete gait cycle includes the execution of specific temporal and spatial parameters that influence overall motor performance. Slower gait speed (velocity) is a parameter that has been associated with falls (Van Kan et al., 2009; Verghese, Holtzer, Lipton, & Wang, 2009; Viccaro, Perera, & Studenski, 2011; Wang et al., 2015). Verghese and colleagues stated that for every 10 cm/s reduction in gait speed there is approximately a 7% increased risk in falling. Middleton, Fritz, and Lusardi (2015) referenced the “Functional Vital Sign”, or walking (gait) speed, to be a predictive measure of functional decline, future health status, and mortality. The basis of this knowledge is conceptually important for understanding how to slow, or reverse, the decrease in gait speed associated with aging. Negative alterations to the gait cycle (e.g., decreased velocity and step length; increased step width and double support time) have been suggested to predict future risk of falls within community-dwelling older adults (Bilney, Morris, & Webster, 2003; Brach,
Exercise can alter the negative effects of the aging process. Even light PA can improve balance and gait performance in older adults (Pau, Leban, Collu, & Migliaccio, 2014). Therefore, physical movement that improves balance, muscular strength and endurance, and flexibility around specific joints associated with the gait cycle are essential to exercise program development. Researchers have reported that structured PA, in the form of multi-component exercise interventions, can significantly reduce the risk of falls (Gillespie et al., 2012). These interventions often include specific exercises that target multiple factors (e.g., balance, flexibility, and strength) associated with the gait cycle. Older adults can potentially decrease fall risks by maintaining regular, moderate-intensity PA on most days of the week. PA recommendations for older adults include a minimum of 30 minutes of aerobic exercise five days per week, coupled with resistance training on two nonconsecutive days per week (ACSM, 2013; Nelson et al., 2007). Resistance training should include a routine of 8-10 anaerobic exercises, at 10-15 repetitions each. Nelson and colleagues (2007) suggested that older adults’ health plans should include an activity plan for reducing sedentary behavior, which incorporates flexibility and balance exercises, and strategies for chronic disease prevention and risk management. Despite these suggestions, exercise adherence remains low, and the prevalence of falls remains high among older adults (Matthews et al., 2008). There is, therefore, a need to implement enjoyable, multidimensional exercise interventions that increase participation to enhance an individual’s gait performance and thereby reduce the risk of falling.
Promoting exercise adherence to increase functional capacity and improve quality of life has been the driving influence for many older adult health promotion and research programs. Low self-efficacy and decreased motivation have been the overwhelming factors associated with low adherence rates (McAuley, Szabo, Gothe, & Olson, 2011). Other barriers to exercise adherence include poor health conditions, chronic pain, and fear of injury (Greaney, Lees, Blissmer, Riebe, & Clark, 2016). Fortunately, methods exist to overcome many of these barriers. The inclusion of socialization and enjoyment into programs are examples of successful methods to improve older adults’ motivation to adhere to exercise recommendations (Costello, Kafchinski, Vrazel, & Sullivan, 2011; Tomlin, & Asinmakopoulou, 2014). Games typically include a social environment and can be enjoyable for participants. The commonly referred Exergaming is the combination of digital games with exercise. Exergaming is a promising method to increase exercise adherence (Skjærø et al., 2016). Exergames include versions called “serious games”, which are designed primarily for learning, where entertainment is not the main reason for playing. These games use digital platforms to improve the learning of health-related content (Wiemeyer, & Kliem, 2011).

Exergames can increase physical activity levels, health education knowledge, and program adherence in older adults (Warburton et al., 2007). Serious games combined with health education can also improve self-efficacy (Thompson, 2012; Cheon, Chung, & Lee, 2015). The combination of increased knowledge and peer support increases a person’s desire and ability to be physically active. The Social-Cognitive Theory includes a comprehensive model, used as a method for developing new behaviors related to increased self-efficacy (Bandura, 1986). In relation to the social-cognitive theory, exercise adherence
is most likely influenced by enjoyable social experiences occurring during gameplay. Overall, exergames provide a unique way to improve the psychological and physiological responses from exercise.

The Bingocize® program is a health promotion program (exergame) that delivers exercise, health knowledge, and cognitive tasks structured within an enjoyable bingo game. Bingo is considered a fun and familiar game for older adults, and can be used as a program enhancer to improve adherence (Crandall, Anderson, & Fairman, 2013; Crandall, Fairman, & Anderson, 2015; Crandall, & Shake, 2016; Crandall, & Steenbergen, 2015). An early version of Bingocize® combined the traditional bingo game with exercise. The version of Bingocize® used in this investigation was a health promotion mobile app designed to include health education (serious game) coupled with exercise (exergame), and intended for the group environment. This investigation included fall prevention and osteoarthritis education, tailored with specific exercises to increase balance and muscular strength and endurance. Researchers have explored the effects of using the app to increase functional performance and health knowledge (Crandall, & Shake, 2016). Prior to this investigation, there were no digital analyses of gait performance before and after using the app.

Older adult physical inactivity decreases gait performance, and therefore, health professionals should focus on methods for increasing exercise participation among this population (Busch et al., 2015). Furthermore, there is a need for activities that promote social engagement to increase self-efficacy, while improving gait performance (e.g., gait speed) to reduce the risk of falling. There is, therefore, a need to investigate socially engaging interventions that increase exercise participation, and enhance gait performance among community-dwelling older adults.
The aim of this investigation was to explore the effects of using the Bingocize® health promotion app, with exercise and health education, as an intervention for improving gait performance among community-dwelling older adults. It was hypothesized that participants using the app including bingo, health education and exercise would significantly improve gait performance compared to participants using the app with only bingo and health education.

**Methods**

*Design*

The present investigation was a 12-week, multi-site, cluster randomized trial. Recruitment included community-dwelling older adults from four independent living facilities located in western Kentucky (3) and northern-middle Tennessee (1). Selection of these facilities was influenced by proximity to the university, and relationships established with management of the facilities. Six groups (clusters) were formed out of recruitment at these four facilities. The minimum number of participants per group was eight in order to better facilitate social interactions among the group members. The maximum group size was set at fifteen to ensure adequate personal attention was available to each participant. Each facility included at least one group, while two facilities formed two groups due to the high number of recruited participants. Groups were randomly assigned to conditions (experimental or control) after pre assessments. Randomization of group assignment was generated using Statistical Package for the Social Sciences (SPSS Version 24) software. Investigators were blinded to all condition assignments throughout the entire investigation. Participants in both conditions used the Bingocize® health promotion app (Figure 1); downloaded onto tablets (DigiLand 16GB Tablets with a 10.1” screen, Chino, CA). The
experimental group used the app, programmed with the bingo game, exercise, and health information, while the control group played the app with bingo and health information, without exercise (Figure 2). Pre-designed templates, created by the investigators, were used during each session. The templates included a predetermined order of exercises, health education or bingo. At the conclusion of each activity (exercise, health education question, or bingo only), participants selected the corresponding number on the game board shown in Figure 2. This pattern would continue until a participant won the bingo game. Small prizes (estimated value at $1.00 per prize) were selected by the bingo game winners. Sessions would continue, with multiple games of bingo, until all health information and or exercises were completed.

**Figure 1.**

Screenshot of Bingocize® Health Promotion Application with Exercise Content and Spinning Number Wheel

*Note.* Twenty-five numbers are included on the wheel. The spinning wheel stops at each number only once per session. Displayed on the tablet are corresponding health-related questions or exercise indicated by the numbered wheel.
**Figure 2.**

Screenshot of Bingocize® Health Promotion Application with Health Education Content and Game Board

*Note.* The 5x5 game board included numbers 1 to 25. Health education questions have multiple-choice answers. Participants select correct answers by touching the screen. Participants touch corresponding numbers on game board, after selection of correct answer.

*Participants*

All participants were community-dwelling older adults aged 60 years and older. The following inclusion/exclusion criteria applied during recruitment; age (≥ 60); must ambulate independently (not wheel chair bound, assisted devices were acceptable); no known severe neurological disorders (e.g., Alzheimer’s, Parkinson’s, dementia); score at least ≥ 17 on the Telephone Mini-Mental State Exam (T-MMSE); no known significant heart-related health concerns (e.g., congestive heart failure); English fluency; ability to see (digital app text on tablets) with or without glasses; and no concurrent health education or structured physical activity programs six months prior to or during this investigation. At
the conclusion of the investigation, each participant was compensated $40.00 for participation in pre and post assessments, and the intervention. The Service Coordinators using attendance sheets, collected at the end of the investigation, monitored overall participation (exercise adherence). At the end of the investigation, a $100.00 drawing was conducted for each group to encourage participation. Only participants present for both pre and post assessments, and attending at least 80% of the intervention sessions (16 of 20), were eligible for this drawing.

Procedures

Recruitment of participants, sites, and groups began after receiving Institutional Review Board (IRB) approval (IRB# 16-230). During recruitment, the researchers provided a 30-minute recruitment presentation to potential participants. Interested participants completed an informed consent document, health assessment questionnaire, and medical release form. Following the recruitment visit, trained university graduate students conducted phone screenings with each participant to complete the T-MMSE. Participants scoring ≤ 17 were excluded from the investigation. Once eligibility was established, pre-assessments were scheduled at each of the four facilities, and the researchers performed assessments at each facility on separate days. All groups (experimental and control) began the Bingocize® intervention the week immediately after the pre-assessment week. The intervention included using the Bingocize® health promotion app twice per week for 10 weeks. The Service Coordinator’s scheduled days and times for sessions for each facility. Each session included using the app to play bingo and to review health education questions. Only the experimental condition included various multi-component exercises (Table 1). The exercises were not specific to gait speed, however,
they were intended to promote improvements in balance, flexibility and strength. Improvements in muscular strength, endurance and flexibility along with cardiovascular endurance, using similar exercise programming, have been reported in previous research (Crandall, Anderson, & Fairman, 2013; Crandall, Fairman, & Anderson, 2015; Crandall, & Shake, 2016; Crandall, & Steenbergen, 2015). During each session, for the experimental condition only, the app included the tailored exercises that alternated with the bingo game and the health education questions. One week after completing the intervention (week 11); researchers returned to repeat assessments at each facility.

At the facilities, Service Coordinators were responsible for assisting the residents. Assistance included health-related information and delivery of social activities. The Service Coordinators were beneficial to both administration and data collection during the investigation. Service Coordinators led the intervention at their respective facility. Prior to week one, investigators provided a workshop to adequately prepare the Service Coordinators to facilitate the intervention. During the intervention, investigators randomly conducted site-monitoring visits to ensure adequate delivery of the Bingocize® health promotion app. Technical assistance, through email or verbal communimion via phone, was available to each Service Coordinator throughout the investigation. At the conclusion of the investigation, each Service Coordinator was compensated $400.00 for their leadership during the sessions and monitoring participation during the investigation.

**Outcomes Measured**

Gait analysis was performed at baseline and post-intervention using the GAITRite® Walkway System (GWS) (CIR Systems Inc., USA). The GWS analysis included temporal (time) and spatial (distance) parameters. Temporal parameters were cadence, velocity, step
time, single support time, and double support time. Spatial parameters were step length and step width. The GWS is a valid and reliable device to measure gait performance (Menz, Latt, Tiedemann, San Kwan, & Lord, 2004). Researchers have used the device to evaluate the risk of falls and the effectiveness of interventions to improve mobility in older adults (Eggenberger, Theill, Holenstein, Schumacher, & de Bruin, 2015).

The GWS model used in this investigation included a flat, straight carpet that provided a safe walking pathway for the older adult participants. Pressure sensors embedded within the GWS carpet recorded digital measurements of the participants’ gait performance. Participants were evaluated at two different speeds. First, participants were instructed to walk across the carpet four times (four separate trials grouped into one test to calculate the gait parameter means) at a normal, self-selected (SS) walking speed. Second, participants were instructed to walk four times across the carpet as fast and as safely as possible. These data were transferred to a secure laptop for analysis. Researchers used similar procedures in previous research studies to collect mean gait performance data (Wang et al., 2015).

Statistical Analysis

Descriptive data were analyzed for all variables. A mixed-design ANOVA was used to examine time (pre/post) x group effects and post hoc analyses using paired and independent samples t-tests were performed for any significant interactions. An independent samples t-test was used to compare adherence between groups. All analyses of assessment data were two-tailed and conducted using SPSS (Version 24). Statistical significance was set at the p < 0.05 level. Effect sizes, using partial eta squared (η²p), were interpreted as small (0.01), medium (0.05), or large effect (0.14) (Cohen, 1988).
Results

Shown in Figure 3, 69 participants met the criteria for the investigation; 48 completed pre-testing; and 38 participants (n=20, experimental; n=18, control) completed the investigation that included pre and post-testing and the app intervention. The mean age for all participants was 72.42 ± 7.54 years. Baseline participant characteristics were similar between conditions (Table 2). Independent t-tests and chi-square tests of independence were performed to examine the within and between relationships of baseline characteristics of participants. No significant differences were observed. The overall retention rate was 79.1% for the duration of the investigation, and participant attrition (10 participants) was associated with scheduling conflicts, desire to increase physical activity beyond the investigation criteria, and health conditions unrelated to the investigation that prevented participation. Based on attendance log data, overall adherence rates for the 12-week investigation were 92% for experimental and 89% for control conditions. Based on an independent samples t-test, no statistical significance was observed for adherence rates between conditions.

Results from the mixed-ANOVA for intervention effects on gait parameters are presented in Table 3. There were no significant main effects for any gait parameters. At fast walking speed, there were significant interactions (group x time), with large effect sizes, in the experimental condition compared to control for velocity (λ = .886, F (1, 36) = 4.61, p = .039, $\eta_p^2 = .114$, Power = .552), and step length (λ = .864, F (1, 36) = 5.64, p = .023, $\eta_p^2 = .136$, Power = .638). No other significant interactions were observed at fast walking speeds. At SS walking speed, there was a significant interaction (group x time), with a large effect size, in the experimental condition compared to control for single
support time \((\lambda = .887, F (1, 36) = 4.59, p = .039, \eta_p^2 = .113, \text{Power} = .550)\). No other significant interactions were observed at SS speed.

Post hoc analyses using paired and independent samples t-tests were conducted on gait variables with observed significant interactions (Tables 5 and 6). The independent samples t-test for Single Support Time (SS) post was significant \((t (36) = 2.454, p = .019, \text{two-tailed})\) (Table 5). None of the remaining post hoc analyses were significant.
Figure 3.  
Participant Flow Diagram

Assessed for eligibility (n=69)

Excluded (n=21)
- Declined to participate (n=19)
- Withdrew (n=1)
- Dropped/unknown (n=1)

Randomized clusters (n=6; average cluster size=8 participants)

Enrollment/Pre-Assessment

Gait analysis (n=48)  
(pre-assessment/double-blinded)

Allocation

Experimental Condition (n=3 clusters)

Control Condition (n=3 clusters)

Allocated to experimental (n=25 participants)

Allocated to control (n=23 participants)

Intervention

Received Intervention (n=21)
- Declined to participate (n=2)
- Withdrew (n=2);
  - Relocated (n=1),
  - Heart condition; not related to the program (n=1)

Received Intervention (n=18)
- Declined to participate (n=2)
- Withdrew (n=3)
  - Relocated (n=1);
  - Injury (hip) (n=1); surgery (n=1); not related to intervention.

Post Analysis

Gait analyzed (n=26)
- Reason unknown/ not present (n=1)

Gait analyzed (n=18)
Table 1. List of Exercises

<table>
<thead>
<tr>
<th>Cardiovascular/Flexibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single arm crossover</td>
</tr>
<tr>
<td>Triceps stretch</td>
</tr>
<tr>
<td>Head turns</td>
</tr>
<tr>
<td>Round &amp; Release</td>
</tr>
<tr>
<td>Trunk Rotation</td>
</tr>
<tr>
<td>Breast Stroke</td>
</tr>
<tr>
<td>Mermaids</td>
</tr>
<tr>
<td>Head half circles</td>
</tr>
<tr>
<td>Calf stretch with chair</td>
</tr>
<tr>
<td>March in place</td>
</tr>
<tr>
<td>Cueing drill</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Balance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Staggered stance</td>
</tr>
<tr>
<td>Ankle flex</td>
</tr>
<tr>
<td>Grapevine</td>
</tr>
<tr>
<td>Static balance (single-leg)</td>
</tr>
<tr>
<td>3-Dot Step with Reach</td>
</tr>
<tr>
<td>Side-to-Side Steps with Arm Swings</td>
</tr>
<tr>
<td>Side steps</td>
</tr>
<tr>
<td>Side steps on balance pad</td>
</tr>
<tr>
<td>Step ups on balance pad</td>
</tr>
<tr>
<td>Heel raises on balance pad</td>
</tr>
<tr>
<td>Walking in place on balance pad</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arm curl</td>
</tr>
<tr>
<td>Lateral raises</td>
</tr>
<tr>
<td>Reverse fly</td>
</tr>
<tr>
<td>Triceps extension</td>
</tr>
<tr>
<td>Leg extension</td>
</tr>
<tr>
<td>Hip abduction</td>
</tr>
<tr>
<td>Heel raises</td>
</tr>
<tr>
<td>Chair squat</td>
</tr>
<tr>
<td>Low row (or bent row)</td>
</tr>
</tbody>
</table>

Note: Exercise descriptions provided in the Bingocize® instructor manual.
Table 2. Baseline Characteristics of Participants

<table>
<thead>
<tr>
<th>Variables</th>
<th>Experimental (n=20)</th>
<th>Control (n=18)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demographics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Female</td>
<td>19</td>
<td>14</td>
</tr>
<tr>
<td>Age (years)</td>
<td>73.30 ± 7.12</td>
<td>71.44 ± 8.07</td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caucasian</td>
<td>14</td>
<td>12</td>
</tr>
<tr>
<td>African-American</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Hispanic/Latino</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Other or Not Reported</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Anthropometrics &amp; Mental State</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height (cm)</td>
<td>158.46 ± 5.84</td>
<td>160.69 ± 10.22</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>83.77 ± 23.81</td>
<td>90.22 ± 18.77</td>
</tr>
<tr>
<td>BMI</td>
<td>33.44 ± 10.13</td>
<td>35.12 ± 7.93</td>
</tr>
<tr>
<td>MMSE</td>
<td>19.68 ± 1.29</td>
<td>20.00 ± 1.07</td>
</tr>
<tr>
<td>Self-Reported Health Conditions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetes</td>
<td>3 (15.0%)</td>
<td>6 (33.3%)</td>
</tr>
<tr>
<td>High Blood Pressure</td>
<td>15 (75.0%)</td>
<td>14 (77.8%)</td>
</tr>
<tr>
<td>High Cholesterol</td>
<td>11 (55.0%)</td>
<td>9 (50.0%)</td>
</tr>
</tbody>
</table>

Data are represented as mean ± standard deviation or total number

*BMI* Body Mass Index

*MMSE* Mini-Mental State Examination
Table 3.
Gait Performance of Participants

<table>
<thead>
<tr>
<th>Variables</th>
<th>Control (n = 18)</th>
<th>Experimental (n=20)</th>
<th>Group x Time</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>Post-Intervention</td>
<td>Baseline</td>
<td>Post-Intervention</td>
<td>$F(1, 36)$</td>
</tr>
<tr>
<td><strong>Velocity (cm/s)</strong></td>
<td>99.70 ± 16.93</td>
<td>97.09 ± 20.34</td>
<td>103.39 ± 23.65</td>
<td>108.41 ± 23.06</td>
<td>1.382</td>
</tr>
<tr>
<td><strong>Cadence (steps/min)</strong></td>
<td>111.85 ± 13.59</td>
<td>111.04 ± 14.03</td>
<td>112.14 ± 16.62</td>
<td>115.13 ± 16.44</td>
<td>1.533</td>
</tr>
<tr>
<td><strong>Step Time (sec)</strong></td>
<td>0.54 ± 0.06</td>
<td>0.56 ± 0.11</td>
<td>0.55 ± 0.08</td>
<td>0.53 ± 0.07</td>
<td>2.130</td>
</tr>
<tr>
<td><strong>Step Length (cm)</strong></td>
<td>54.17 ± 10.14</td>
<td>52.96 ± 11.34</td>
<td>55.12 ± 7.92</td>
<td>56.41 ± 8.23</td>
<td>1.116</td>
</tr>
<tr>
<td><strong>Step Width (cm)</strong></td>
<td>9.09 ± 1.02</td>
<td>8.99 ± 1.01</td>
<td>8.70 ± 1.02</td>
<td>8.14 ± 0.85</td>
<td>2.783</td>
</tr>
<tr>
<td><strong>Single Support (%GC)</strong></td>
<td>33.40 ± 2.12</td>
<td>32.16 ± 3.26</td>
<td>34.22 ± 3.01</td>
<td>34.63 ± 2.95</td>
<td>4.594</td>
</tr>
<tr>
<td><strong>Double Support (%GC)</strong></td>
<td>33.58 ± 4.12</td>
<td>35.70 ± 6.85</td>
<td>31.52 ± 6.12</td>
<td>31.10 ± 5.90</td>
<td>2.900</td>
</tr>
<tr>
<td><strong>Velocity (cm/s)</strong></td>
<td>128.73 ± 24.38</td>
<td>121.21 ± 25.52</td>
<td>122.21 ± 29.54</td>
<td>128.61 ± 25.67</td>
<td>4.611</td>
</tr>
<tr>
<td><strong>Cadence (steps/min)</strong></td>
<td>127.93 ± 12.07</td>
<td>125.55 ± 15.69</td>
<td>124.64 ± 16.96</td>
<td>126.60 ± 15.57</td>
<td>1.742</td>
</tr>
<tr>
<td><strong>Step Time (sec)</strong></td>
<td>0.47 ± 0.04</td>
<td>0.48 ± 0.07</td>
<td>0.48 ± 0.07</td>
<td>0.48 ± 0.06</td>
<td>1.806</td>
</tr>
<tr>
<td><strong>Step Length (cm)</strong></td>
<td>60.84 ± 11.83</td>
<td>58.22 ± 11.42</td>
<td>58.56 ± 9.95</td>
<td>60.86 ± 9.28</td>
<td>5.646</td>
</tr>
<tr>
<td><strong>Step Width (cm)</strong></td>
<td>9.04 ± 1.06</td>
<td>9.06 ± 0.97</td>
<td>8.68 ± 1.05</td>
<td>8.29 ± 0.89</td>
<td>1.967</td>
</tr>
<tr>
<td><strong>Single Support (%GC)</strong></td>
<td>35.09 ± 2.17</td>
<td>34.16 ± 2.94</td>
<td>35.67 ± 2.74</td>
<td>35.70 ± 2.73</td>
<td>2.887</td>
</tr>
<tr>
<td><strong>Double Support (%GC)</strong></td>
<td>30.36 ± 4.28</td>
<td>31.50 ± 5.71</td>
<td>29.06 ± 5.46</td>
<td>28.99 ± 5.47</td>
<td>1.268</td>
</tr>
</tbody>
</table>

Baseline and Post-Intervention values are mean ± standard deviation

* $P < 0.05$, statistically significant interaction
%GC Percentage of time during gait cycle

a Self-selected walking speed; b Fast walking speed
Table 4. Compared Means for Velocity

<table>
<thead>
<tr>
<th>Condition Assignment</th>
<th>Velocity (^a) (cm/s)</th>
<th>Velocity (^a) (cm/s)</th>
<th>% Change</th>
<th>Velocity (^b) (cm/s)</th>
<th>Velocity (^b) (cm/s)</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>Post</td>
<td></td>
<td>Baseline</td>
<td>Post</td>
<td></td>
</tr>
<tr>
<td>Experimental (n=20)</td>
<td>Mean</td>
<td>103.39</td>
<td>108.42</td>
<td>4.86</td>
<td>122.22</td>
<td>128.61</td>
</tr>
<tr>
<td></td>
<td>Std. Deviation</td>
<td>23.65</td>
<td>23.06</td>
<td></td>
<td>29.55</td>
<td>25.67</td>
</tr>
<tr>
<td></td>
<td>Minimum</td>
<td>70.30</td>
<td>68.10</td>
<td></td>
<td>76.60</td>
<td>71.60</td>
</tr>
<tr>
<td></td>
<td>Maximum</td>
<td>152.30</td>
<td>145.10</td>
<td></td>
<td>181.60</td>
<td>172.40</td>
</tr>
<tr>
<td>Control (n=18)</td>
<td>Mean</td>
<td>99.71</td>
<td>97.09</td>
<td>-2.62</td>
<td>128.73</td>
<td>121.21</td>
</tr>
<tr>
<td></td>
<td>Std. Deviation</td>
<td>16.93</td>
<td>20.34</td>
<td></td>
<td>24.38</td>
<td>25.52</td>
</tr>
<tr>
<td></td>
<td>Minimum</td>
<td>72.10</td>
<td>50.20</td>
<td></td>
<td>68.70</td>
<td>68.10</td>
</tr>
<tr>
<td></td>
<td>Maximum</td>
<td>131.00</td>
<td>130.30</td>
<td></td>
<td>176.30</td>
<td>155.90</td>
</tr>
</tbody>
</table>

\(^a\) Self-selected walking speed  
\(^b\) Fast walking speed

Baseline Pre-Intervention assessment  
Post Post-Intervention assessment
Table 5.
Post Hoc Independent Samples T-Tests of Significant Interactions Observed

<table>
<thead>
<tr>
<th></th>
<th>Levene's Test for Equality of Variances</th>
<th>t-test for Equality of Means</th>
<th>95% Confidence Interval of the Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F</td>
<td>Sig.</td>
<td>t</td>
</tr>
<tr>
<td>Velocity_F_Pre</td>
<td>1.318</td>
<td>.259</td>
<td>-.737</td>
</tr>
<tr>
<td>Single Support_SS_pre</td>
<td>1.554</td>
<td>.221</td>
<td>.967</td>
</tr>
<tr>
<td>Single Support_SS_post</td>
<td>.380</td>
<td>.541</td>
<td>2.454</td>
</tr>
</tbody>
</table>

* = p < .05

F Fast walking speed
SS Self-selected speed
Pre Pre-Intervention assessment
Post Post-Intervention assessment
<table>
<thead>
<tr>
<th>Pair</th>
<th>Paired Differences</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
<th>95% Confidence Interval of the Difference</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pair 1</td>
<td>Velocity_F_Pre - Velocity_F_Post</td>
<td>.197</td>
<td>20.900</td>
<td>3.390</td>
<td>-6.672 - 7.067</td>
<td>.058</td>
<td>37</td>
<td>.954</td>
</tr>
<tr>
<td>Pair 2</td>
<td>Step Length_F_pre - Step Length_F_post</td>
<td>.031</td>
<td>6.762</td>
<td>1.097</td>
<td>-2.191 - 2.254</td>
<td>.029</td>
<td>37</td>
<td>.977</td>
</tr>
<tr>
<td>Pair 3</td>
<td>Single Support_SS_pre - Single Support_SS_post</td>
<td>.375</td>
<td>2.476</td>
<td>.401</td>
<td>-.439 - 1.189</td>
<td>.933</td>
<td>37</td>
<td>.357</td>
</tr>
</tbody>
</table>

p < .05

*F* Fast walking speed

*SS* Self-selected speed

*pre* Pre-Intervention assessment

*post* Post-Intervention assessment
Discussion

The purpose of this investigation was to evaluate the effectiveness of the Bingocize® health promotion app to improve gait performance in community-dwelling older adults. Based on our results, using the app combined with the exercise intervention did not produce statistically significant main effects. However, using the app combined with the exercise did produce significant interactions for velocity and step length at fast walking speeds, and single support time at SS speeds. Post hoc analyses revealed that single support time (SS) was significant ($p = .019$) (Table 5). This interaction was due to the reduced performance within the control condition (Table 3). The remaining observations were not statistically significant (Tables 6). However, a meaningful increase in mean gait velocity was observed for participants in the experimental condition, compared to the control condition (Table 4). The mean velocity at SS and fast walking speeds increased 5.23 cm/s in the experimental condition. This increase in gait speed exceeded the 5.0 cm/s suggested to represent a small, yet important clinical change (Perera et al., 2006). According to Perera and colleagues, the recommended criteria for a meaningful change in gait speed should be 5 cm/s (small) to 10 cm/s (large).

Normal walking speed varies between 120-140 cm/s, and is dependent on age, gender and various anthropometric measures (Lerner-Frankiel, Vargas, Brown, Krusell, & Schoneberger, 1986). For older adults, gait speed is typically lower and decreases with age. There are clinical implications to decreased gait speed, and falling below certain cut-off points can increase the risk of adverse health events (Fritz, & Lusardi, 2009). In an earlier white paper by Fritz and Luusardi (2009), the authors illustrated these cut-off points
in gait speed, reported by previous researchers. Based on these reports, it appears that 100 cm/s (or 1.0 m/s) is a significant cut-off point for gait speed, where older adults are in need of interventions to improve gait speed and help prevent adverse health outcomes. During our investigation, control participants would be considered at high risk for adverse health events due to the lower gait speeds observed when walking at SS speed (97.09 cm/s), and therefore, may benefit from an intervention to increase gait performance (Lusardi, 2012) (Table 4). Based on the results of this investigation, it is plausible that if participants in the control condition followed the experimental protocol they would have received a meaningful change in gait speed (+5 cm/s), which could increase their gait speed above the 100 cm/s threshold for SS walking speed. There is, therefore, a reason to believe that participants using the app with the same exercise protocol may continue to increase gait velocity over time. This finding is clinically significant for both decreasing the risk of falling and increasing the ability to preserve cardiovascular health.

Community-dwelling older adults need the ability to ambulate safely and independently. Researchers recommend an upward of 130 cm/s for fast walking speeds, to safely navigate specific environmental conditions such as crossing a multi-lane street (Salbach et al., 2014). In the present investigation, participants’ mean velocity, at post-intervention for fast walking speeds, was below 130 cm/s in both conditions (Table 4). Based on these results, many of these participants would not be able to reach or maintain the recommended velocity for crossing certain streets safely.

To summarize, it is suggested that older adults need to maintain SS walking speeds greater than 100 cm/s (Middleton et al. 2014), and fast walking speeds over 130 cm/s (Salbach et al., 2014). Thus, emphasis should be placed on increasing both SS and fast
walking speeds over time in order to increase independence and safety for community-dwelling older adults (Arantes et al., 2015). In contrast, decreased gait speed, monitored over time, may suggest a health-related problem is present that may require a medical evaluation (Studenski et al., 2011). During the investigation, mean gait velocity for participants in the control condition decreased for both SS and fast walking speeds (Table 4). Based on the recommendations from Studenski and colleagues (2011), these older adults should be clinically monitored over time to ensure there is not a continuing decline in gait speed. We suggest, with older adults over time, using the Bingocize® health promotion app and exercise protocol may improve gait parameters associated with walking speed, potentially reduce the risk of falling, and improve the quality and safety of independent living.

Based on these results, we suggest that the meaningful changes observed for gait speed during this investigation were related to the exercise protocol used in the experimental condition, and therefore, supports the ACSM’s position stand (1998) that exercise increases physical performance factors in older adults. Future researchers, exploring the associations between gait and exercise, should also include the FITT (Frequency, Intensity, Type and Time) principle used within set protocols. Assessing and comparing outcomes from multiple investigations is needed to further understand specific relationships associated with varied exercises and older adults’ gait cycle. During this investigation, the exercise intervention included moderate level exercise for approximately twenty minutes in duration, on two days per week, for ten weeks. The frequency of training used during this investigation was at lower levels (two days per week compared to three or more days per week) than that noted in the literature (Rubenstein et
The type of exercises used during this investigation were multi-component, yet were not specific to gait (Table 1). However, while not significant, the change in mean gait speed over time within the experimental condition may have been a response to these exercises and the FITT principle factors utilized during the intervention. Based on observed alterations in gait speed, within the experimental condition, we suggest that moderate level, multi-component exercise at low frequency (two days per week) and time (20-30 min.), can provide a meaningful change in gait speed and may potentially decrease the risk of falling in community-dwelling older adults.

There are many factors (e.g., mental, physical, environmental) associated with a decreased risk of falling. Many federally approved evidence-based fall prevention programs focus on exercise and health knowledge to improve physical, mental and environmental factors (Stevens, & Burns, 2015). This investigation included fall-related health information to increase health knowledge, and exercises to improve physical health. The combination of increased fall prevention awareness and exercise can increase self-efficacy (related to falls) and reduce the risk of falling (Rose, 2008). Unfortunately, this investigation did not include a falls self-efficacy scale. However, it is possible that the changes in gait performance were a result of a decreased sense of fear associated with falling, and improved self-efficacy.

Adherence to exercise programs is essential to reduce the risk of falls via increased physical adaptations associated with exercise (US Department of Health and Human Services, 2008). Older adults remain mostly sedentary, not participating in aerobic or anaerobic physical activity or exercise, which increases the risk of falls (Matthews et al., al. 2000; Wang et al., 2014; Zhuang et al., 2014).
In the present investigation, participants in the experimental condition maintained high adherence rates (92%) to exercise. Utilization of the app may have been a factor associated with adherence. In addition, participants were encouraged with prizes during the bingo games, and each were paid to participate in the investigation. To eliminate bias, the payment was nominal and the same for both conditions. Additionally, the overall retention rate was 79.1%, with attrition unrelated to the intervention. Over 75% of participants within this investigation had at least one chronic health condition. Future studies should eliminate incentives (e.g., prizes and payments) to effectively test overall adherence rates to the app intervention. However, observations from this investigation highlight the potential effectiveness of this health promotion app to increase physical activity and health knowledge for improving the health and quality of life of community-dwelling older adults with chronic conditions.

The intervention protocol and app design were intentional. The overall structure was created so that individuals within a community can use mobile technology to offer the Bingocize® health promotion program to community-dwelling older adults within a traditional activity environment. Furthermore, the investigators suggest that adherence and outcomes observed during this investigation support the Bingocize® health promotion app as a potential public health intervention to increase awareness of falls and participation in physical activity, and thereby, reduce the risk of falling.

There were limitations to this investigation. Based on our sample, the results of this investigation may not be generalized to the overall population of community-dwelling older adults. Additionally, it is plausible that an increased sample size, or intervention time, could have altered the observed results. Another possible limitation was awarding
bingo game prizes, which may have confounded overall program retention and adherence rates. However, bingo games traditionally offered within these facilities will often award similar prizes to participants, and therefore, we suggest participation was unaltered by the prizes.

Future research using similar methods reported from this investigation should be aimed to the following recommendations. Researchers should include alterations in the FITT principle and its association to gait performance in community-dwelling older adults. Additionally, joint kinematic and kinetic measurements would enhance this type of investigation. For example, kinematic measurements (video recording) can provide visual data elements to identify alterations to range of motion, and angular motion and speeds applied to specific joints. Furthermore, a visually observed improvement in gait may aid in identifying additional fall risk reduction. Kinetic measurements can provide data to identify alterations in force applied to the body during walking. These measurements can provide information on how participants were able to make changes in velocity and related gait variables. Additionally, force measurements could be beneficial in helping discern which exercises are the best for improving specific gait parameters.

Next, researchers should explore the association of decreased gait speed and cognitive decline using the mobile health promotion app. Middelton and colleagues (2015) suggested a cognitive decline in five years after gait speed fell below the recommended minimum baseline (1.0 m/s). Many of the participants within the control condition were already at risk for cognitive decline, and these participants stand to benefit from the meaningful change in gait speed observed within the experimental condition of this investigation. Furthermore, exploring the effects of varied and specific exercise
interventions on gait and cognition is warrented. Lastly, the Bingocize® health promotion app used in this investigation is tailorable for specific individual needs. The utility of the app allows a program leader to create modifiable templates for each participant. These modified templates could include varied, personalized exercise prescriptions that are deliverable through the tablet to each participant independently. This approach could be utilized to explore the relationships between gait speed, exercise, and cognition, or with other variables, per individual.

Lastly, future investigations of gait performance stand to benefit from a subjective measurement using a falls efficacy scale (e.g., Falls Efficacy Scale-International). Evaluating self-efficacy could help researchers better understand the relationships between physiological responses to exercise and psychological changes to self-efficacy.

In conclusion, the utilization of this health promotion app, with a modified template including exercises designed to improve balance and muscular strength, can produce a meaningful detectable change in gait speed in community-dwelling older adults. Based on this observation, we suggest that gait performance will significantly improve over time from participating in the experimental intervention, and therefore supports our alternative hypothesis. From a public health perspective, it was important that older adults sustained physical activity during this investigation while using the Bingocize® health promotion app tailored with exercise. In addition, this app could help motivate older adults to maintain recommended physical activity levels. However, further investigations of the app without incentivized (e.g., prizes, payments) participation are warranted to validate adherence and motivation among older adults. The National Council on Aging and the Centers for Disease Control and Prevention promote physical activity as a method for
reducing the risk of falls. Increasing participation in physical activity is imperative due to the current prevalence of chronic disease and conditions, low physical activity rates and incidence of fall-related injuries among this population. Therefore, there is a continual need for programs that motivate individuals to improve their physical health. The older adult population needs increased physical activity levels, and the Bingocize® health promotion app appears to provide an enjoyable experience for participants to adhere to exercise programming. Lastly, by using the Bingocize® health promotion app, increasing gait speed, and maintaining physical activity, community-dwelling older adults may decrease the risk of falling.

Acknowledgements

This investigation was funded by the Retirement Research Foundation.

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on Gait, Functional Mobility, Fear of Falling, and Falls in Prefrail Older Women: A Randomized Clinical Trial. *Topics in Geriatric Rehabilitation, 31*(2), 113-120.


Chapter 5: Summary

The importance of fall prevention among older adults is well established. The percent of the older adult population is increasing. Researchers and clinicians should inform, educate and provide interventions to reduce the risk of falling among older adults. This investigation served to increase the efficacy of the mobile app version of the Bingocize® health promotion program. The results of this investigation help support the efficacy of Bingocize® as an evidence-based intervention to help reduce the risk of falls among community-dwelling older adults.

During this investigation, there were additional outcomes that occurred during facility recruitment, program workshops (intervention leader training) and intervention delivery. There were four facilities recruited for this investigation. These facilities now provide partnership opportunities to help sustain the Bingocize® intervention, and increase future research opportunities in western Kentucky and northern-middle Tennessee. Within these facilities, four trained Bingocize® program leaders added to the field, thus providing the ability to increase future program delivery. Lastly, thirty-eight community-dwelling older adults received health knowledge related to fall prevention and osteoarthritis. These additional “beneficial” outcomes may now serve to increase the current and future health status of individuals affiliated with these facilities.

At the conclusion of this investigation, analysis of gait performance data did not produce significant main effects. Overall, the evidence of this investigation did not support the alternative hypothesis that using the app with exercise, health knowledge and bingo would significantly improve gait performance in community-dwelling older adults.
The overall gait performance involves multiple temporal and spatial parameters operating in cycles. Gait speed is a specific temporal parameter suggested to predict future falls and other adverse health outcomes among older adults. Furthermore, there is clinical significance when referring to gait speed in older adults. Previous research includes normative values for gait speed. Additionally, researchers suggest that both positive and negative alterations in gait speed at 0.1 m/s have clinical implications. Researchers have supported using gait speed as a predictor for adverse health outcomes in older adults. During this investigation, gait speed increased by over 5 cm/s for both fast and SS walking speeds for the experimental condition. This increase in gait speed was reported as a small, yet meaningful change. There is, therefore, reason to believe that community-dwelling older adults using the app, with the exercise intervention protocol, may continue to increase gait speed and potentially decrease the risk of falling.

Decreasing the risk of falling is a national public health focus. The CDC and the NCOA are national leaders in falls prevention education, and have clearly defined their vision and goal for increasing physical activity to improve fall prevention in the U.S. Both organizations use a rigorous method of selecting evidence-based interventions. In addition, the Administration on Aging supports many of these interventions. Many of these evidence-based interventions are currently available to help community-dwelling older adults reduce the risk of falling; however, they typically do not include a fun game environment like Bingocize®. The approach of using a game appears to increase socialization, suggesting an increase in self-efficacy and motivation among this population group. Likewise, using the app appeared to help maintain adherence rates (≥89%) in both conditions during the intervention. Based on this investigation, and
combined with previous research, the Bingocize® health promotion app may serve as an evidence-based public health intervention to reduce the risk of falling. There is, however, a need for further investigations on the improvements in functional performance (upper and lower extremity strength and endurance), health knowledge, and self-efficacy, for determination of where improvements in gait performance derive from using the Bingocize® program.

Future investigators should focus on using multiple measurements to increase the overall efficacy of the app. Functional performance in both upper and lower extremities is important for the maintenance of ADLs. The assessment of strength and endurance can quantify the effectiveness of the app for both upper and lower muscular adaptations. Additionally, kinematic and kinetic gait assessments can provide data related to specific joint movements and force application. This information can help researchers discern the relationships between exercise and changes in torque applied at certain joints during the gait cycle. Results from these types of assessments might provide additional support to existing research on how muscular strength affects gait performance. Furthermore, health knowledge is important for helping community-dwelling older adults become better self-managers of their personal health and safety. Knowledge gained from fall prevention education and osteoarthritis awareness may improve self-management of health resulting in overall improvements in health status and quality of life. Future investigations should include the assessment of health knowledge and before and after using the Bingocize® health promotion app. Health knowledge should not be exclusive to only fall prevention and osteoarthritis in future studies. Investigators need to explore the efficacy of the app to improve self-management and health knowledge in various chronic diseases and
conditions (e.g., diabetes). Utilization of evidence-based fall assessments (e.g., CDC’s “Stopping Elderly Accidents, Deaths & Injuries” (STEADI) toolkit) should be considered in future investigations as well. The STEADI toolkit includes fall prevention awareness information for providers and patients. It also includes functional assessments (i.e., Timed-Up-and-Go (TUG) Test; 4-Stage Balance Test, and 30-Second Chair Stand Test). These assessments could be useful in determining the efficacy of a fall prevention intervention. Lastly, increased (falls) self-efficacy can decrease the risk of falling. In contrast, a lower falls self-efficacy, and fear of falling, can actually increase the risk of falling. There is, therefore, a need to test falls self-efficacy, and perception of fear of falling, in future studies related to the Bingocize® health promotion program, and other fall reduction interventions.

There appears to be a link to declining gait speed and cognition. Using the app combined with assessment of gait and cognition could add to clinical significance of the program. In addition, the outcomes could add to existing literature on the gait speed to cognition relationship. The app can be tailored to address individual needs and exercise prescriptions. Furthermore, the app can be used onsite within a particular group or room, or can be used remotely. This offers a unique opportunity for both researcher and participant.

Researchers may gain from the overall understanding of the FITT principle as it applies to fall reduction interventions. Clinical evaluations of gait speed appear to predict adverse health outcomes, however specific exercise prescriptions (FITT) based on an individual’s “usual” gait performance appear to be lacking. The FITT criteria utilized during this investigation were lower in frequency (days) and duration (time) than many
previous studies. The significance of the FITT principle appears to have implications in the outcomes of gait performance. It is worth noting that our FITT criteria did produce a meaningful change in gait speed among older adults participating in the experimental condition. Therefore, future research should examine the effectiveness of varying the FITT components and report on the differences in gait performance outcomes.

In summary, the Bingocize® health promotion app appears to be an effective evidence-based intervention leading to meaningful changes in gait performance of community-dwelling older adults. Additionally, the app can provide motivation to older adults to participate in recommended levels of exercise. Lastly, it is unclear if the social component of the game (bingo) may be the element that provides the needed improvements in self-efficacy and adherence to recommended levels of exercise for older adults.


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mobility in frail elderly patients. *Journal of Clinical Epidemiology, 61*(2), 186-191.


## Appendix A

### Exercise Descriptions

<table>
<thead>
<tr>
<th>WARM-UP EXERCISES</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Single arm crossover</strong></td>
<td>Gently pull one arm across chest below the chin. Hold and repeat with opposite arm</td>
</tr>
<tr>
<td><strong>Triceps stretch</strong></td>
<td>Extend right arm straight up, palm facing forward. Bend your right elbow, letting your hand hinge down behind your head as if you were patting yourself on the back. With your left hand, place hand on right elbow, gently pulling until you feel a stretch down the back of your upper arm. Repeat with left arm.</td>
</tr>
<tr>
<td><strong>Head turns</strong></td>
<td>With straight posture, slowly and gently turn head towards the left and hold for a few seconds. Repeat with right side. Do not hyperextend the head!</td>
</tr>
<tr>
<td><strong>Round &amp; Release</strong></td>
<td>Participants sit tall, on the edge of a sturdy chair, with feet on the floor about hip-width apart. Cue to feel the weight on their “sit bones” and tailbone, which is about 0.5 inch above the chair. Weight is on the sit bones but NOT on the tailbone. Cue to exhale, sit back — back into the chair...how about curl backward, flexing the lower spine while firmly contracting the abdominals. Imagine pulling the navel to the spine and cue to rock back onto the tailbone into a posterior pelvic tilt. Then, cue to inhale and sit as tall as possible. They should feel their tailbone lift up and off the chair as the weight shifts to their “sit bones,” with the pelvis in a neutral position. The spine also lifts into good upright neutral alignment. Cue to lengthen the neck and lift the chest (Sanders, 2013).</td>
</tr>
<tr>
<td><strong>Trunk Rotation</strong></td>
<td>Participants to sit on the edge of the chair, with feet on the floor shoulder-width apart. “squeeze shoulder blades slightly together.” Have participants reach arms out to the sides, as if they were making a “T” (90 degrees, shoulder abduction) while maintaining scapular retraction. Cue participants to twist the upper body to the right and pulse, gently pushing further three times into spinal rotation, exhaling with each pulse. Inhale and return to center, then repeat to the left (Sanders, 2013).</td>
</tr>
<tr>
<td>Exercise</td>
<td>Description</td>
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<tr>
<td>Breast Stroke</td>
<td>Participants to sit on the edge of their chair in good alignment, with feet about hip-width apart on the floor, pelvis in neutral, spine long and tall, crown of the head high. Lift the arms to bring the hands in front of the chest, reaching forward. Perform a breast stroke, turning the hands from palms down to palms up. Arms should move horizontally while performing horizontal shoulder abduction. Simultaneously, cue to lift the chest so the thoracic spine actively extends. Have participants inhale as their head and neck continue to stretch the spine upward. Remind participants to keep the shoulder blades stabilized, down and back or “packed and grounded” while performing retraction. Cue to exhale as the arms return to the start position in front of the chest (Sanders, 2013).</td>
</tr>
<tr>
<td>Mermaids</td>
<td>Participants should begin by sitting on the edge of the chair, feet hip-width apart on the floor, spine erect and in neutral. Place one hand on the side of the chair for support. Then have them inhale and perform a continuous motion, sweeping the opposite arm out to the side and up overhead. Encourage participants to exhale as they continue the motion, moving through full range and finally into a side bend (spinal lateral flexion) where they pause, inhale, and return back to the starting position. Repeat on the other side (Sanders, 2013).</td>
</tr>
<tr>
<td>Head half circles</td>
<td>Gently rotate head forwards until chin reaches center of chest. Now, slowly rotate head backwards until eyes are directed upwards. Repeat with both sides. Do not hyperextend the head!</td>
</tr>
<tr>
<td>Calf stretch with chair</td>
<td>Place both hands on a chair. With one leg bent at a 90-degree angle and the opposing leg straight, lean into chair. Heels should not rise off the floor.</td>
</tr>
<tr>
<td>March in place</td>
<td>Most individuals have either performed a march, or have seen one. Perform this exercise by walking in place (the pace will be a little quicker than walking). However, on every step raise the knee so that the hip and knee both reach near 90 degrees of flexion. Make sure to pump arms back and forth; this will add to the cardiovascular benefit as well as preparing the shoulder girdle for movement. Note: participants may perform a slower march focusing on good knee and hip flexion.</td>
</tr>
</tbody>
</table>
**Cueing drill**

This exercise is designed to enhance cognitive recognition of a verbal command; thus challenging the central nervous system to quickly respond with physical movement. Begin exercise in an open area with a clear pathway twenty feet in front and behind the body (note, that in a group the participants will form a straight line. Leave a few feet in-between each participant. The front of the line should have a clear pathway, and the end of the line should have a clear pathway behind them.)

- Example Verbal Cues: Forward (walk)
- Stop (no walk)
- Backward (walk)
- Turnaround (180° turn; face opposite direction)
- Break-it down (bent knees at approximately 120°; place hands on knees)
- Up (full extension of legs and back; ready for walking)
- Clap x# of times (ex: clap twice; clap ten times)
- Right Foot-Up (single-leg stance)
- Left Foot-up (single-leg stance)
- Down (after foot-up command)
- Right Foot Forward (right foot steps forward; left arm reaches forward)
- Left Foot Forward (left foot steps forward; right arm reaches forward)
- Together (after Right < or Left >, feet are brought back together and arms return to the body)
- Up on Your Toes (resembles a calf raise exercise; participants stay up until the down command is given by the instructor)
- Down
- Look Right (head turns to the right)
- Center (head returns to the center/forward position)
- Look Left (head turns to the left)

During the drill, the participants should continue the command until instructed to change the movement.
Try challenging participants by mixing up the commands and changing the tempo.

<table>
<thead>
<tr>
<th>BALANCE EXERCISES</th>
<th>Description</th>
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<tr>
<td><strong>Exercise</strong></td>
<td><strong>Description</strong></td>
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<tr>
<td>Staggered stance</td>
<td>Being with feet together and hands at sides. Step forward with your right foot. Maintain this position for 10 seconds. Alternate putting the other foot in front.</td>
</tr>
<tr>
<td>Ankle flex</td>
<td>While standing on one leg, spell a word using the non-supporting leg. Repeat with opposite leg.</td>
</tr>
<tr>
<td>Grapevine</td>
<td>Begin standing with arms at sides, feet together. Step across in front of your left foot with right leg. Continue to step sideways uncrossing the right leg. Take 3 steps then reverse and cross your right leg behind your left leg. Continue to step sideways, uncrossing the left leg. Repeat 3 times in each direction</td>
</tr>
<tr>
<td>Static balance (single-leg)</td>
<td>Stand on a balance pad with eyes focused forward, arms crossed over the chest, and one leg elevated to about ankle level without touching the support leg. Repeat with opposing leg.</td>
</tr>
<tr>
<td>Exercise</td>
<td>Description</td>
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<tr>
<td>3-Dot Step with Reach</td>
<td>This exercise is designed to change the center of gravity while moving forward, sideways, and backwards. During the movement, use the arms by reaching out in the same direction of the step. Begin by standing with feet together and arms down to the sides of the body. Select a side to train. Note that during this exercise the opposite foot should never leave the ground. Now on the side chosen to work, take a step lunge forward (<em>lunge; slightly bending front knee</em>), about 2-3 feet. During this stepped lunge reach the arms out in front, away from the body. Now return to the starting position. Now with the same foot, step out to the side, about 2-3 feet; during the step reach your arms out in the same direction of the step (to the side). Return to the starting position. Now step backwards about 2-3 feet, while allowing the arms to open backwards into a horizontal reach (hands together extended out from chest, open arms along the horizontal plane. Continue to open arms until they are 180° apart). Note that when the backwards step is made, the front knee will bend and the back leg (stepped leg) will remain straight. Return to the starting position. Repeat these three steps 5 times on both sides of the body.</td>
</tr>
<tr>
<td>Side-to-Side Steps with Arm Swings (<em>Modified Skiers</em>)</td>
<td>Sidestep one direction and bring the opposite foot behind the stepped leg. Repeat this movement in the opposite directions. Let the arms swing naturally side-to-side in the movement of the stepped direction. Perform the side-to-side steps for 30 seconds.</td>
</tr>
<tr>
<td>Side steps</td>
<td>Ensure that participants are more than 5 feet apart from one another. Begin with feet together and arms at your side. Either right or left, begin side stepping to the direction the arm is pointed. Note that the feet should come back together between each side step. Also, avoid turning out the lead foot. Ensure that both feet remain facing forward during the entire exercise. While stepping, add a lateral shoulder raise with the arm of the step direction. Relax arm down when feet are brought together. Perform equal repetitions in both directions.</td>
</tr>
</tbody>
</table>
Heel raises on balance pad | Older adults are asked to raise their heels off the pad while keeping their knees straight. Hold this position for about 6 seconds, then slowly lower heels to the floor. Note: a chair may be used for support.

Walking in place | Walk in place for a designated time period. Older adults should focus more on correct form rather than number of steps. Older adults should mimic a march

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Description</th>
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<tbody>
<tr>
<td>Arm curl</td>
<td>Place the resistance band beneath both feet. Hands should be gripping band handles with palms facing inward. While holding the upper arm stationary, curl the band forward. ONLY THE FOREARMS SHOULD MOVE. After biceps have fully contracted, slowly bring hands back to the starting position.</td>
</tr>
<tr>
<td>Lateral raises</td>
<td>While seated, place resistance band beneath both feet. With hands gripping handles, slowly raise arms in front until parallel with the floor. Hold for a few seconds and slowly release to starting position.</td>
</tr>
<tr>
<td>Reverse fly</td>
<td>Hold resistance band directly in front of chest. Arms should be extended away from body and straight. While holding the rubber portion of the band, slowly pull arms away from older adults’ center, allowing band to stretch across chest. Once band has been fully extended, slowly release to starting position.</td>
</tr>
<tr>
<td>Triceps extension</td>
<td>With your left hand, place one end of the resistance band on your right shoulder. With right hand, extend arm</td>
</tr>
<tr>
<td>Leg extension</td>
<td>While seated, extend right foot. Slowly return to starting position and repeat with left foot.</td>
</tr>
<tr>
<td>Hip abduction</td>
<td>Using a chair for support, participants are asked to slowly raise one leg out to the side of their body, keeping their foot flexed. Then lower back toward their standing leg, keeping their hips centered.</td>
</tr>
<tr>
<td>Heel raises</td>
<td>While standing behind a chair for support, participants raise their heels off the ground while keeping their knees straight. Slowly lower heels to the ground. Repeat this activity for desired reps.</td>
</tr>
<tr>
<td>Chair squat</td>
<td>This exercise requires a chair and stable ground to stand on. Begin by sitting in the chair with your arms extended straight out in front of you. Now engage your leg muscles so that you stand up out of the chair. Refrain from leaning forward. Also, make</td>
</tr>
</tbody>
</table>
sure you do not sway side to side. If this exercise is too challenging, then add a sturdy support, such as another person, chair, counter top, table, etc. Repeat exercise by returning to the seated position. Note: Posture control is the same when transferring the body from a seated to standing position and standing to seated position. Tip: During the exercise imagine a line that extends upward from the end of your toes. Try to keep your head and knees behind this line.

| Low row (or bent row) | During this exercise make sure to maintain alignment of the back. Once you are in the starting position, begin drawing your hands straight back towards your sides, near the armpits. While drawing your arms back, your elbows will bend; make sure they stay in tight near your sides. During the motion, squeeze the muscles together in the mid back to help draw in the resistance band. Imagine there is a tennis ball between your shoulder blades, and you are trying to hold it there using only your back muscles. This will help engage many muscles in your back and arms. Once the weights reach the side of the body, begin slowly lowering the resistance band back to the starting position. |
Appendix B

Informed Consent Document

WKU IRB #16-230

INFORMED CONSENT DOCUMENT

Project Title: Efficacy of a mobile application for improving older adults’ health, function, and cognition

Co-Investigators: Dr. Jason Crandall, Western Kentucky University, School of Kinesiology, Recreation, and Sport; Jason.crandall@wku.edu or 270-745-2077 or Dr. Matthew Shake, Western Kentucky University, Department of Psychological Sciences; matthew.shake@wku.edu

You are being asked to participate in a project conducted through Western Kentucky University. The University requires that you give your signed agreement to participate in this project.

The investigator will explain to you in detail the purpose of the project, the procedures to be used, and the potential benefits and possible risks of participation. You may ask any questions you have to help you understand the project. A basic explanation of the project is written below. Please read this explanation and discuss with the researcher any questions you may have.

If you then decide to participate in the project, please sign this form in the presence of the person who explained the project to you. You should be given a copy of this form to keep.

1. Nature and Purpose of the Project:
   The benefits of physical activity participation in older adults include slowing the physical changes related to aging, promoting psychological and cognitive well-being, managing chronic diseases, improving health-related quality of life, and increasing longevity. Exercises that specifically focus on functional fitness variables, such as balance, strength and flexibility, are important factors for preventing falls in older adults.

   Although the benefits of physical activity have been well documented, very few older adults participate in recommended amounts for preventing falls and improving quality of life. Fortunately, researchers have identified factors that will motivate older adults to participate in physical activity. Some of these factors are moderate intensity exercise, group-based interventions, and increasing self-confidence, improving attitudes toward physical activity, and providing social support for activity.

   WKU IRB# 16-230
   Approval - 12/10/2015
   End Date - 12/10/2016
   Expedited
   Original - 12/10/2015
Given the need to develop programs that increase physical activity, cognition, and health education in older adults, the purpose of the study is to test the effectiveness of a 10-week Bingocize® program for improving functional fitness (e.g., upper body and lower body strength, endurance, and flexibility), executive function, and health education.

2. **Explanation of Procedures:**
   If you agree to be in this study, you will be asked to do the following **BEFORE** and **AFTER** the study:
   - Complete four (4) questionnaires
   - Have your height, weight, and blood pressure measured
   - Complete six (6) physical tests of upper and lower body muscular strength, endurance, and flexibility. These tests will include: (a) lower body muscular strength (e.g., number of times you can stand up and sit down in a chair in 30 seconds), (b) upper body muscular strength (e.g., number of bicep curls you can do with a light dumbbell in 30 seconds), (c) lower body flexibility (e.g., chair sit and reach test—the distance you can reach forward toward your toes while sitting in a chair), (d) upper body flexibility (e.g., back scratch test—how far your hands can reach behind your neck), (e) cardiovascular fitness (e.g., stepping in place) and a (f) balance test.
   - Complete several cognitive tests assessing aspects of your attention, memory, and reasoning.

Once you complete the testing above, you may be asked to attend weekly Bingocize sessions during a 10-week period. Bingocize is a mobile application that combines exercise, health education, and bingo game. These sessions will last approximately 60 minutes and will occur twice a week. There is a possibility that you will not be selected to participate in Bingocize and instead be randomly assigned to a group that plays Bingo and learns health-related information.

3. **Discomfort and Risks:**
   Emotional stress may occur due to not being able to complete exercises, answer health education questions losing in bingo. Physical injury is possible with any type of physical exercise/exertion—although every effort will be made to use proper progressions and exercises with participants.

**WKU IRB# 16-230**
Approval - 12/10/2015
End Date - 12/10/2016
Expedited
Original - 12/10/2015
4. **Benefits:**
The potential direct benefits to include improved fitness level, including improved cardiorespiratory fitness, muscular strength, balance, flexibility, and aspects of cognitive function. In addition, there are social benefits from participating in community-based exercise programs. You may also see improvement in the knowledge and understanding of the health education information presented and then the subsequent use of that information.

5. **Confidentiality:**
The answers you provide on the survey, the functional fitness data, and the cognitive data we collect are confidential, which means that your responses/results will only be known by Dr. Crandall, Dr. Shane, and their team of investigators. Your identity as a participant in this research study will be kept confidential in any publication of the results of this study. The information obtained during this research (research records) will be kept confidential to the extent permitted by law. However, this research record may be reviewed by government agencies, individuals who are authorized to monitor and audit this research, or the Institutional Review Board (the committee that oversees all research in human subjects at Western Kentucky University) if required by applicable laws or regulations. The material will be maintained for up to 3 years.

6. **Refusal/Withdrawal:** Refusal to participate in this study will have no effect on any future services you may be entitled to from the University. Anyone who agrees to participate in this study is free to withdraw from the study at any time with no penalty.

*You understand also that it is not possible to identify all potential risks in an experimental procedure, and you believe that reasonable safeguards have been taken to minimize both the known and potential but unknown risks.*

---

Signature of Participant

Date

Witness

Date

THE DATED APPROVAL ON THIS CONSENT FORM INDICATES THAT
THIS PROJECT HAS BEEN REVIEWED AND APPROVED BY
THE WESTERN KENTUCKY UNIVERSITY INSTITUTIONAL REVIEW BOARD
Paul Mooney Human Protections Administrator
TELEPHONE: (270) 745-2129

[Stamp: WKU IRB# 16-230
Approval - 12/10/2015
End Date - 12/10/2016
Expedited
Original - 12/10/2015]
Appendix C

Physician’s Release

PHYSICIAN’S RELEASE

Patient’s Name ____________________________

Title:

This page will give you the information you will need to understand why this program is being done and why your patient is being invited to participate. It will also describe any known risks, inconveniences or discomforts that your client may have while participating. We encourage you to ask questions at any time, including via email or phone.

➤ PURPOSE AND BACKGROUND

The benefits of physical activity participation in older adults include slowing the physical changes related to aging, promoting psychological and cognitive well-being, managing chronic diseases, improving health-related quality of life, and increasing longevity. Exercises that specifically focus on functional fitness variables, such as balance, strength and flexibility, are important factors for preventing falls in older adults.

Although the benefits of physical activity have been well documented, very few older adults participate in recommended amounts for preventing falls and improving quality of life. Various reasons for this lack of participation in physical activity include discomfort, fear of injury, social isolation, and fear of falling. Fortunately, researchers have identified factors that will motivate older adults to participate in physical activity. Some of these factors are moderate intensity exercise, group-based interventions, and increasing self-confidence, improving attitudes toward physical activity, and providing social support for activity.

Given the need to develop programs that increase physical activity in older adults, the purpose of the program is to improve functional fitness (e.g., upper body and lower body strength, endurance, and flexibility).

➤ PROCEDURES

Participants will be asked to do the complete physical tests of upper and lower body muscular strength, endurance, and flexibility. These tests include, but are not limited to: (a) lower body muscular strength (e.g., number of times you can stand up...
and sit down in a chair in 30 seconds), (b) upper body muscular strength (e.g., number of bicep curls you can do with a light dumbbell in 30 seconds), (c) balance tests, and (d) a gait test.

Each session will last approximately 60 minutes and will occur two times per week. During the sessions, exercises will be alternated with bingo number calling. Participants who win BINGO and those who excel during the exercise sessions (e.g., best attitude, most reps completed, etc.) will receive small prizes at the end of each session.

➢ RISKS
Potential risks from participation in the program are typical of those related to participating in physical activity. Specifically, there is a risk of physical injury or discomfort, including muscle soreness. However, we will do our best to ensure that the program progresses gradually and that you are given ample instructions as to how to perform exercises safely or how to perform modifications if your patient cannot do specific exercises.

➢ BENEFITS
The direct benefits to your patient include the potential to improve physical health, including your cardiorespiratory fitness, muscular strength, balance, and flexibility. In addition, there are social benefits to participating. Finally, we will award small prizes to bingo winners.

➢ QUESTIONS
If you have any questions or concerns about your patient’s participation in this program, please call Dr. Jason Crandall at 270-745-2007.

Physician’s Signature ____________________________ Date ______________

Printed name ________________________________
Appendix D

Health Screening Survey for Older Adults

<p>| | |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td><strong>Name of participant</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Date of Birth</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Date</strong></td>
<td></td>
</tr>
</tbody>
</table>

For most people physical activity should not pose any problems or hazards. This Health Screening Survey has been designed to identify the small number of adults for whom physical activity might be inappropriate or those who should have medical advice concerning the type of activity most suitable for them. Common sense is your best guide in answering these few questions. Please read them carefully and check the correct answer opposite the question if it applies to you.

<p>| | |</p>
<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td><strong>YES</strong></td>
<td><strong>NO</strong></td>
</tr>
<tr>
<td>1. Do you get chest pain while at rest and/or during exertion?</td>
<td></td>
</tr>
<tr>
<td>2. If yes to #1 above, is it true that you have not had a physician diagnose those pains yet?</td>
<td></td>
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<tr>
<td>3. Have you had a heart attack?</td>
<td></td>
</tr>
<tr>
<td>4. If yes to #3 above, was your heart attack within the last year?</td>
<td></td>
</tr>
<tr>
<td>5. Do you have high blood pressure?</td>
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</tr>
<tr>
<td>6. Do you know if you have diabetes?</td>
<td></td>
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<tr>
<td>7. If the answer to #6 is yes, are you presently being treated for diabetes?</td>
<td></td>
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<tr>
<td>8. Are you short of breath after extremely mild exertion, at rest, or at night in bed?</td>
<td></td>
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<tr>
<td>9. Do you have ulcerated wounds or cuts on your feet that do not seem to heal?</td>
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<tr>
<td>10. As an adult, have you ever had a fracture in the hip, spine, or wrist?</td>
<td></td>
</tr>
<tr>
<td>11. Have you undergone joint replacement surgery? Joint:   Year:</td>
<td></td>
</tr>
<tr>
<td>12. Do you get pain in your buttocks, thighs (front or back), or calves when you walk?</td>
<td></td>
</tr>
<tr>
<td>13. While at rest, do you frequently experience fast, irregular heartbeats? Or, at the other extreme, very slow beats?</td>
<td></td>
</tr>
<tr>
<td>14. Are you currently being treated for any heart or circulatory condition, such as vascular disease, stroke, angina, hypertension, congestive heart failure, poor circulation to the legs, valvular disease, blood clots or pulmonary disease?</td>
<td></td>
</tr>
<tr>
<td>15. Have you previously undergone either coronary angioplasty or heart bypass surgery, or both?</td>
<td></td>
</tr>
<tr>
<td>16. Have you fallen more than twice in the past year (no matter what the reason)?</td>
<td></td>
</tr>
</tbody>
</table>

Based upon the above answers and your Medical History, you may be asked to have your physician complete the form below PRIOR to participating in Fitness Appointments.

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**Physician’s Release Form**

My patient, ________________, is medically healthy to participate in a fitness assessment/exercise program.

<table>
<thead>
<tr>
<th>Physician’s Signature</th>
<th>Date</th>
</tr>
</thead>
</table>

Type or Print Physician’s Name:  ____________________________  Physician’s Phone Number:  ____________________________

Restrictions/Comments: __________________________________________________________________________________________

Please sign/fax back to: 270-745-6043 or  
Email to: jason.crandall@wku.edu

Adapted from Alamogordo Physical Therapy  
& Wellness Center
Appendix E

Health Questionnaire

Date: ____________________________________________________ ID#________

Age: _______ Sex: M  F

Race/Ethnicity (please circle one):
1. Caucasian
2. African-American
3. American Indian
4. Hispanic/Latino
5. Other

Highest Level of Education (please circle one)
1. Less than high school
2. High school
3. Associate’s Degree
4. Bachelor’s Degree
5. Graduate Degree

Personal Address:
Street ____________________________________________
City ____________________________ State ____________ Zip ____________

Phone (Cell): ____________________________

Email address: ____________________________

In case of emergency, whom may we contact?
Name: ____________________________ Relationship: ____________________________
Phone (Cell): ____________________________ (Home): ____________________________

Personal physician
Name: ____________________________ Phone: ____________________________
Fax: ____________________________

Present/Past History
Have you had or do you presently have any of the following? (Check if yes.)

______ Rheumatic fever
______ Recent operation
______ Edema (swelling of ankles)
______ High blood pressure
______ Low blood pressure
______ Injury to back or knees
______ Seizures
______ Lung disease
______ Heart attack or known heart disease

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___ Fainting or dizziness
___ Diabetes
___ High Cholesterol
___ Orthopnea (the need to sit up to breathe comfortably) or paroxysmal (sudden, unexpected attack) or nocturnal dyspnea (shortness of breath at night)
___ Shortness of breath at rest or with mild exertion
___ Chest pains
___ Palpitations or tachycardia (unusually strong or rapid beat)
___ Intermittent claudication (calf cramping)
___ Pain, discomfort in the chest, neck, jaw, arms, or other areas
___ Known heart murmur
___ Unusual fatigue or shortness of breath with usual activities
___ Temporary loss of visual acuity or speech, or short-term numbness or weakness in one side, arm, or leg of your body
___ Cancer
___ Other (please describe): ______________________________________

Activity History

1. Have you participated in an exercise program within the last 30 days? Yes _____ No _____ If yes, briefly describe the program: ______________________________________________________

2. Have you ever performed resistance (weight) training exercises in the past? Yes _____ No _____

3. Do you have injuries (bone or muscle disabilities) that may interfere with exercising? Yes _____ No _____ If yes, briefly describe: ____________________________________________________

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Appendix F

Health Knowledge Test

PLEASE CIRCLE THE CORRECT ANSWER. THERE IS ONLY ONE CORRECT ANSWER! DO NOT CHOOSE MORE THAN ONE ANSWER. ANSWER ALL QUESTIONS.

1. Where do the majority of falls occur?
   a. Within the home
   b. Walking in the park
   c. At work
   d. Hiking in the woods

2. What are the three best types of exercises to do if you have osteoarthritis?
   a. Flexibility, strengthening, and endurance exercises
   b. High impact exercises, limited range of motion exercises, lunges
   c. Deep squats, full-arc knee extensions, non-flexibility exercises
   d. None of the above

3. What is the leading cause of hospital admission for older adults?
   a. Heart attacks
   b. Falling
   c. Car wrecks
   d. Stroke

4. What is the most common type of arthritis?
   a. Osteoarthritis
   b. Felty’s Syndrome
   c. Lupus
   d. Fibromyalgia
5. There are both internal (things inside the body) and external (things outside of the body) risk factors for falling. Some **internal** risk factors would include:
   - a. A person’s physical environment
   - b. Footwear
   - c. Neurological/cognitive disorders (ex: Parkinson’s disease)
   - d. Lack of physical activity/exercise

6. Some **external** (things outside of the body) risk factors for falling would include:
   - a. Normal age-related changes
   - b. Disease
   - c. Unsafe home environments
   - d. Poor balance

7. What causes arthritis?
   - a. Genes
   - b. Lifestyle
   - c. Environment
   - d. The cause is unknown

8. Certain medications or combinations of medications can increase the risk of falling.
   - a. True
   - b. False

9. It is not possible to have more than one form of arthritis at a time.
   - a. True
   - b. False

10. Sources of dietary vitamin D that can help prevent falling include:
   - a. Dark green leafy vegetables
b. Fruit juices  
c. Fortified cereals  
d. All of the above

11. Among three main types of treatment for arthritis are non-drug therapies, surgery, and _____________.
   a. Medications  
b. There are no other treatments  
c. Cognitive therapy  
d. Chemotherapy

12. Osteoarthritis mostly occurs in the:
   a. Hand  
b. Hip  
c. Spine  
d. Knee

13. Those who fall are _______ times more likely to fall again:
   a. 1 – 5  
b. 2 – 3  
c. 4 – 9  
d. 3 – 4

14. Which of the following is an environmental risk factor for falling?
   a. Previous fall history  
b. Psychoactive medications  
c. Impaired judgment  
d. Wet floors

15. There are fixed risk factors and lifestyle risk factors for arthritis. Which of the following is a fixed risk factor?
   a. Overweight and obesity
b. Gender  
c. Joint injuries  
d. Infection

16. There are fixed risk factors and lifestyle risk factors for arthritis. Which of the following is a lifestyle risk factor?
   a. Age  
b. Genetics  
c. Occupation  
d. Race

17. When it comes to falling, rugs do more harm than good.
   a. True  
b. False

18. What is the most common cause of traumatic brain injuries?
   a. Car wrecks  
b. Bumping your head on a wall  
c. Direct contact with another person’s head  
d. Falling

19. Exercising with arthritis:
   a. Is harmful and should not be done  
b. Is only for when you first develop it  
c. Has no benefits  
d. Is helpful in improving quality of life/managing pain

20. Which of the following foods should you avoid eating if you have arthritis?
   a. Cherries  
b. Salty preservatives
c. Cheese/dairy

d. Broccoli

21. What is the percentage of hip fractures caused by falls?
   a. 80%
   b. 95%
   c. 65%
   d. 40%

22. When rising from a lying or sitting position, __________ is a common cause of falls due to dizziness or fainting.
   a. Low blood pressure
   b. High blood pressure
   c. Getting up too slowly
   d. None of the above

23. Which of the following is one of the best foods to eat if you have arthritis?
   a. Fish
   b. Fried foods
   c. Salty preservatives
   d. Corn oil

24. The most common reason for falling in older adults is:
   a. Dizziness/vertigo
   b. Accident/environment
   c. Gait/balance disorder
   d. Visual problems

25. Muscle-strengthening exercises should be performed _______ or more days per week.
   a. 5
   b. 2
   c. 3
26. Doing less physical activity reduces your risk for falling
   a. True
   b. False

27. Which of the following is a **fixed** risk factor for osteoarthritis?
   a. Age
   b. Excess body mass
   c. Occupation
   d. Muscle weakness

28. Which of the following is a **lifestyle** risk factor for osteoarthritis?
   a. Gender
   b. Race
   c. Knee pain
   d. Genetics

29. What is the leading cause of hospital admission for older adults?
   a. Heart attacks
   b. Falling
   c. Car wrecks
   d. Stroke

30. Pain and anti-inflammatory medications for osteoarthritis are only available as pills.
   a. True
   b. False