Effect of Dual-Task Training on Balance and Cognition

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Introduction

The aim of this study is to evaluate the literature regarding balance exercises and their correlation with performance scores of cognitive testing. This is often referred to as dual-task training or dual-task balance evaluation. Much of the literature is written in regard to post-concussion evaluation, also referred to as mild traumatic brain injury (mTBI or TBI). Common and concerning symptoms of a concussion include decreased cognitive performance, as well as altered gait and balance. This is why concussion evaluation tests often include measures of cognitive ability, via verbal and visual retention, as well as balance-gait tasks such as standing on one foot. The literature written within the past ten years indicates that there is a correlation between cognitive test scores and balance performance. Based on previous literature, this paper will look to examine the effectiveness of dual-task cognitive training on improving both balance and cognitive retention scores.

Statement of the Problem

The problems to be addressed in this study involve decreases in balance ability as people age, develop illnesses, or become injured. Specifically, the correlation between cognitive ability and balance performance will be studied. Balance disorders can be dangerous for anyone, but specifically older individuals that are more prone to injury after falling. The American Geriatrics

Society Health in Aging Foundation reported in December of 2020 that, “Nearly 8 million adults of all ages in the United States report balance disorders each year. About 25% of older adults in the community report difficulty with balance or require the assistance of another person or special equipment to walk,” (AGS Health, 2020, para. 14). Balance disorders can occur for a variety of reasons, including decreased muscular strength and neurological coordination due to aging, neurological illnesses such as Parkinson’s disease, or varying levels of traumatic brain injuries including concussions (Howell, Osternig, and Chou, 2018).

Concussions are a common form of traumatic brain injury (TBI). According to a study done by the Regents of the University of Michigan (2022), it has been found that in the United States alone there are around 3.8 million concussions reported per year by athletes. This means that in any given sports season, 5-10% of participants will experience a concussion (Regents of the University of Michigan, 2022). Additionally, it is important to note that this begins at an early age, as there is approximately 8.3% of children age 12-17 that report concussions yearly according to the CDC (Black and Zablotsky, 2020). Complications that are often associated with a concussion are decreased cognitive performance, such as short and long-term memory, as well as decreased balance or coordination. Expanding on the frequency of cognitive and balance complications, Parkinson’s disease is a prevalent neurological disorder that can complicate activities of daily living in those diagnosed due to symptoms such as trembling that can impact balance. The Parkinson Foundation estimated in 2022 that there are one million people in the United States, as well as six million people worldwide, that have the disease (Parkinson Foundation, 2022).

There are other neurological disorders in addition to Parkinson’s disease, such as Huntington’s and Hemiballismus, which all affect the basal ganglia in the brain. The basal

ganglia is explained by Lanciego, Luquin, and Obeso as, “A group of subcortical nuclei responsible primarily for motor control, as well as other roles such as motor learning, executive functions and behaviors, and emotions. . .Disruption of the basal ganglia network forms the basis for several movement disorders" (Lanciego et al., 2012, p. 1). Riva, Taddei, and Bulgheroni (2018) further explain that:

> Basal Ganglia (BG) are involved not only in motor sequencing, motor skills and complex actions, but also in the modulation of higher order cognitive functions, mood regulation and non-motor complex behaviors that need to process and integrate different types of information (para. 2).

The prevalence of balance complications as well as the juxtaposition of these accepted models of basal ganglionic function suggest a neuroanatomical justification for a more in-depth look into how dual-task training can be used to increase a person’s ability to perform activities of daily living.

Purpose of the Study

The purpose of the study is to perform a retrospective study about the correlation between performance on cognitive tests, such as verbal and visual retention tests, and performance on balance testing. After identifying this correlation, the effectiveness of dual-task training on the improvement of both cognition and balance will be examined. Information will be drawn from jury-reviewed journal articles about the effectiveness of this kind of training, as well as identified portions of the research that need to be further studied in order to draw complete conclusions about which methodology produces the greatest results in a given population.

Research Questions

The following research questions will be addressed:

- What is the correlation between performance on cognitive testing and performance on balance testing?
- Has cognitive training been shown to enhance performance on balance testing and vice versa?
- Is dual-task training an effective way to enhance both cognitive and balance performance?

Theoretical Perspective

The theory of this study is that by evaluating jury-reviewed journal articles, a relationship will be established between cognitive and balance abilities as well as the efficacy of dual-task training on the enhancement of one's ability to perform cognitive tasks and activities of daily living. According to a systematic review of the literature regarding the efficacy of combined treatments on patients with acquired brain injuries in comparison to monotherapies, recovery was enhanced due to combined therapies. The results are explained by the complexity of damage done during a brain injury or illness, which suggests that a series of increasingly complex tasks would be more effective in more-fully restoring neurological function (Mala and Rasmussen, 2017). Another study done on male collegiate lacrosse players found that there was a significant relationship between balance and neurocognition in this population (Klima, Hood, Madden, Bell, Dawson, McGill, and Patterson, 2022). Operating under this theory by Mala and Rasmussen (2017), as well as the theory that cognition and balance are correlated, further research can be examined to determine which methodology is most appropriate for the restoration of balance and cognitive function.

Definition of Terms

The following terms will be frequently used in the explanation of the topic of this paper. All definitions were pulled from the Wikimedia Foundation (2022) and reviewed for accuracy and applicability by the author of this paper.

- Traumatic Brain Injury (TBI) – Also known as an intracranial injury, is an injury to the brain caused by an external force. TBI can be classified based on severity, ranging from mild to severe.
- Parkinson's Disease – A long-term degenerative disorder of the central nervous system that mainly affects the motor system. Usually associated with tremors, rigidity, slowness of movement, and difficulty walking. Cognitive and behavioral problems may also occur.
- Balance – The ability to maintain the line of gravity of a body within the base of support with minimal postural sway.
- Gait – The pattern of movement of the limbs during locomotion.
- Cognition – The mental action or process of acquiring knowledge and understanding through thought, experience, and the senses. Encompasses perception, attention, thought, intelligence, memory, evaluation, reasoning, problem-solving, decision-making, and comprehension.
- Cognitive Testing – Assessments of the cognitive capabilities of humans via various forms of IQ tests, memory, and retention tests.
- Concussion – Also known as a mild traumatic brain injury (mTBI). It temporarily affects brain functioning. Symptoms include loss of consciousness, memory loss, headaches; difficulty with thinking, concentration, or balance; nausea; blurred vision; sleep disturbances; and mood changes.

- Dual-task training – A form of physical or cognitive training that involves the administration of multiple motor tasks, cognitive tasks, or a combination of motor and cognitive tasks.

Delimitations and Limitations

This study was limited to peer-reviewed journal articles found on EBSCOhost and PubMed databases. In order to ensure relevant and up-to-date information was being used, all articles were published within ten years of the start date of this study (2012). Topics of discussion within the journal articles ranged from neurological illnesses, concussions, the correlation between cognitive and balance test performance, and the efficacy of cognitive and balance monotherapies on the improvement of test scores, as well as the efficacy of dual-task training.

A limitation to the review of literature is that the research is still in its infancy, meaning that the number of concrete conclusions are limited. This is explained by Mala and Rasmussen (2017), who mentions that there is data to suggest that combined treatments are more effective than monotherapies, but the evidence cannot be considered conclusive due to the limited amount of data. Further expanding on this, a study was done on working memory load between individuals with and without balance impairments following a mTBI. While the study did find a link between impaired balance and modulation of cognitive resources in patients with mTBI, it was noted that, "Future studies should seek to elucidate whether remediation of these cognitive factors, such as impaired working memory, lead to improved balance control and changes in neural activity when integrated into a comprehensive balance rehabilitation programme.," (Woytowicz, Sours, Gullapalli, Rosenberg, and Westlake, 2018, p. 9). This again suggests the correlation between cognition and balance, as well as the fact that researchers are heading toward

the conclusion that a combination of the two would be most effective in evaluating and treating patients with TBI, but there is still more research to be done that would require a large quantity of patients willing to be studied.

Significance of the Research

Provided that the information gathered from the retrospective study is applicable to a variety of populations, it demonstrates the potential to advance the methods of evaluation and treatment of neurological dysfunctions through physical therapy. Referring again to the prevalence of balance disorders (AGS Health in Aging Foundation, 2020), concussions in the United States (Regents of the University of Michigan, 2022), and Parkinson's Disease (Parkinson Foundation, 2022), it is evident that further research on this topic has the potential to help a wide range of people. In summary, as education for health professions is always changing, if it is found that dual-task training has a significant impact on the rehabilitation of those with neurological dysfunctions, it is imperative that this information enter the curriculum.

Review of the Literature

The review of literature for this study will aim to examine three themes. The first is the correlation between physical training, including balance training, and improved cognitive ability. The second, is the effectiveness of cognitive dual-task training as a means of improving balance. Finally, the third is an examination of the application of cognitive dual-task training as a form of therapy to patients struggling with cognitive frailty due to injury or disease.

Theme 1: The correlation between physical/balance training and cognitive performance

The first part of the study is to establish the correlation between physical activity, including balance training, and its effect on improving cognitive performance. A study was done

using male collegiate lacrosse players in an attempt to determine said correlation. The study, done by Klima, Hood, Madden, Bell, Dawson, McGill, and Patterson (2022), explains that there is little known about the relationship between balance and cognition prior to an injury, which is an important baseline concerning the later application to methods of recovery post-injury. Baseline testing in athletics is important because it will serve as a criterion measure of an athlete's level of recovery following a brain injury. Based on the immediate post-concussion test, which measures visual and verbal memory, reaction time, and processing speed, as well as a sensory organization test implemented by the researchers, it was found that there is a significant association between balance and both verbal memory and visual motor speed scores (Klima et al., 2022). Furthermore, they make the claim: "Findings warrant ongoing performance and executive function tracking and can serve as a conduit for integrated sensorimotor and dual-task training," (Klima et al., 2022, p. 1) which serves as a gap statement for the topic of this paper.

Expanding on the concept of baseline testing as a measure of a person's recovery post-injury, it is important to understand how baseline testing is conducted. The Centers for Disease Control and Prevention (2015) explains that baseline testing often takes place prior to a season of athletics so that healthcare providers know what each athlete's performance level on these tests is prior to an injury. Athletes, as well as non-athletes, should complete a baseline test each year to maintain an accurate standard. A baseline test consists of a symptom survey, where participants will be asked to give a subjective rating of a variety of potential concussion symptoms. Additionally, the administrator of the test will use either computerized or paper-pencil neuropsychological tests to gauge the participant's overall concentration, memory, and reaction time capabilities. If a person were to sustain a head injury, the administrator would repeat the

same survey and tests to compare the results with the initial baseline. The comparison would be used to measure the extent of damage and the rate of recovery.

With a correlation between cognition and balance being demonstrated, whether or not the training of one can impact the performance of the other needs to be investigated. A systematic review and meta-analysis of the literature on interventions to improve cognitive frailty in older adults (60+ years) was performed on peer-reviewed journal articles between 2013-2021. The review was done by Tam, Chan, Cheung, Ho, Tang, Christensen, and Kwan (2022). Of the two thousand five hundred six studies that were identified, eight were included in the meta-analysis. The primary conclusion from the review was that physical activity was a component of all reviewed interventions in the improvement of cognitive frailty, and it was shown that the interventions were effective in improving cognitive functions, although they were not always effective in the improvement of physical frailty (Tam et al., 2022). Extensive amounts of research have been done to show that physical activity can improve cognitive function, as is supported by this systematic review.

Another systematic review by Lal, Kolakowsky-Hayner, Ghajar, and Balamane (2018) explains that exercise had a positive impact on cognitive performance in people that had suffered a concussion. Using the standards of the same immediate post-concussion testing as Klima et al. (2022), it was found that physical activity improved the reaction time and memory scores aspects of the test, demonstrating cognitive improvement from exercise. Additionally, Lal et al. (2018) found that scores improved on the balance error scoring system as a result of physical activity, and there was a reduction on the post-concussion symptom scale, which again suggests a positive relationship between exercise and recovery following a TBI.

A study done by Kara Kaya and Ayse Zengin Alpozgen (2022), compares the effects of aerobic exercises and pilates exercises on cognitive functioning. While there were positive correlations for both groups, there was a larger increase in the Nelson's Speed of Movement Test for the pilates group, an exercise type that emphasizes balance and strength more than aerobic capacity (Kaya and Alpozgen, 2022). The population of this study was young adults, aged 18-25 years. The authors mention that this age group is often participating in academic education, which requires concentration, attention, and rapid shifts between complex tasks. They claim that the dorsolateral prefrontal circuit in the prefrontal cortex is essential for these functions: "The prefrontal cortex manages sensory input and motor output processes involving complex cognitive and emotional behaviors," (Kaya and Alpozgen, 2022, p. 135). This is suggestive of the relationship between cognition and the ability to perform physical functions due to the neurological overlap within the brain.

Furthermore, Kaya and Alpozgen (2022) discuss the descriptions from other authors, which explain that the same prefrontal lobe region is responsible for: "selective attention, inhibitory control, rapidly shifting mental sets, verbal fluency, and speed of movement, a psychomotor function in which cognitive and physical functions work together," (Kaya and Alpozgen, 2022, p. 135). This demonstrates how the same region of the brain can be responsible for primarily cognitive tasks as well as tasks that are critical to successful motor task performance.

Woytowicz, et al. (2017), support this connection between the cognitive and motor regions of the brain by using magnetic resonance imaging in their study comparing the working memory of those who have experienced balance impairments following mTBI and those who have not experienced balance impairments following mTBI. They explain that the balance

impaired group experienced stronger connectivity of the pre-supplementary motor cortex during the working memory task. Additionally, while the balance-impaired group had decreased activation of the salience and central executive networks when compared to the non-impaired group, which are regions of the brain responsible for attention and working memory such as problem-solving, the default mode network was the most suppressed region in the balance-impaired group, which is responsible for passive tasks and passive thoughts. This means that proportionally, the balance-impaired group had higher levels of stimulation in regions of the brain that control motor functions and working memory during dual-task activities than the non-impaired group. This is indicative of an effective method of recovery as it targets the desired regions of the brain, it reinforces the findings by Kaya and Alpozgen (2022), and it encourages further research.

Theme 2: Dual-task training on balance and gait ability

As the research has demonstrated, it is theorized that physical activity is correlated to cognitive performance, such that training of the body can impact the ability of the mind. To expand on this, there are studies that have been done in order to determine the most effective training modalities. A study that examined the effects of single-task, dual-task, and successive physical-cognitive training on balance performance and fall risk in older adults (73 +/- 4.6 years), found that "dual-task training consisting of cognitive and motor activity has a positive additional effect on fall frequency due to improvement in gait initiation, dual-task costs of walking and divided attention," (Atas, Sogukkanli, Erdogan, and Hanoglu, 2022, p. 8). However, it was also observed that in this population, certain tests such as the Berg Balance Scale and Timed Up and Go tests were improved more in the group that performed successive cognitive and motor tasks, rather than simultaneous tasks (Atas et al., 2022).

Another study examined the same relationship between integrated dual-task training and consecutive dual-task training. However, this study by Yuzlu, Oguz, Timurtas, Aykutoglu, and Polat (2022) was done over a period of eight weeks compared to the four-week study by Atas et al., (2022). While both methods were effective in the improvement of balance and gait, it was concluded that, "the impact of integrated and consecutive dual-task balance training on balance and gait performance in older adults was not statistically significantly different," (Yuzlu et al., 2022, p. 1). Furthermore, the authors go on to state that their study suggested that consecutive dual-task balance training can serve as an alternative method to simultaneous training in populations that are not capable of performing the more complex integrated dual-task activities (Yuzlu et al., 2022). This suggests that both simultaneous and successive dual-task training activities can be effective in rehabilitative settings, although it may be recommended to use the successive method as a progression toward simultaneous cognitive dual-task training.

Relating this information to the working networks of the brain following an injury, Elizabeth Woytowicz et al., (2017) did a study using magnetic resonance imaging to compare functional connectivity of cognitive brain regions during working memory tasks in patients with TBI and resultant balance impairments. The study found that there was stronger connectivity of left pre-supplementary motor cortex in the balance impaired group during the working memory task. The authors said that these results were suggestive of a link between impaired balance and modulation of cognitive resources in patients with mTBI. The authors claim that, "Findings also highlight the potential importance of moving beyond traditional balance assessments towards an integrative assessment of cognition and balance in this population," (Woytowicz et al., 2017, p. 1). This shows support for the use of cognitive dual-task training in the evaluation and treatment of brain injuries that result in balance impairments, rather than singularly balance assessments.

Theme 3: Dual-task training as a method of treatment for TBI, disease, or cognitive frailty

As previously mentioned, there is little research regarding the effectiveness of dual-task training on the improved recovery of patients following TBI, disease, or cognitive frailty. It is known that exercise and cognitive ability have a positive correlation, but with the research being in its infancy, it is important to the fields of physical and occupational therapy that cognitive dual-task training continue to be studied and applied to improve recovery. This section of the literature review will examine peer-reviewed journal articles that have applied cognitive dual-task training to diagnostic or therapeutic settings.

A study was done by Howell, Osternig, and Chou (2018) to determine the more effective way of detecting acute and long-term effects of a concussion. The studied modalities were dual-task gait balance control and computerized neurocognitive testing. The researchers found that there were significant differences between the concussed group and the control group in center-of-mass displacement during dual-task gait testing, as well as visual memory testing. However, the computerized neurocognitive test was not predictive of how individuals would perform on the dual-task gait balance test. The conclusion that the authors drew from the study was that, "Dual-task assessments concurrently evaluating gait and cognitive performance may allow for the detection of persistent deficits beyond those detected by computerized neurocognitive deficits alone," (Howell et al., 2018, p. 2). The authors of this study believe that a combined method, such as cognitive dual-tasks, may be more effective in evaluating the extent of damage following a brain injury.

This study by David Howell et al. (2018) coincides with the findings by Woytowicz et al. (2018). "A fundamental component of postural control is the ability to dedicate cognitive resources to meet postural demands. Recent dual task paradigms, combining postural and

cognitive tasks, have revealed important relationships between attention, balance, and fall risk," (Woytowicz et al., 2017, p. 2). This information considered, it is imperative to evaluate cognition and balance concurrently in order to examine the full extent of the damage following an injury. Additionally, it is just as important to train these mechanisms concurrently in order to effectively recover from an injury and prepare patients for activities of daily living that will require cognitive function during a motor task.

As the field of physical therapy continues its attempts to improve rehabilitation techniques, a study was done on different types of dual-task training to determine which was the most effective in improving dual-task gait performance in individuals with Parkinson's disease. People that have Parkinson's disease have gait impairments, which are often aggravated under dual-task conditions. This can affect the quality of daily living. This study, done by Yang, Cheng, Lee, Lie, and Wang (2019), compared cognitive dual-task training with motor dual-task training. This means that one group was asked to perform a cognitive task while also performing various types of gait, such as answering questions while walking both forward and backward. The other group performed motor tasks during various types of gait, such as bouncing a basketball while walking both forward and backward. After doing this for three days a week for four weeks, it was found that cognitive dual-task training improved motor dual-task walking performance and single-task walking performance in regard to gait speed, stride length, and double-support time. Motor dual-task training was more effective at decreasing stride time variability during dual-task walking (Yang et al., 2019). The important takeaway from this study is that there are multiple types of dual-task training that can be beneficial to those with balance impairments, and it is likely that a variety of methodologies should be implemented in order to yield the best results.

An article by Hana Mala and Camilla Pihl Rasmussen (2017) talks about the potential effectiveness of combined therapies on the recovery of a brain injury as opposed to monotherapies. The authors point out that there have only been a few therapeutic approaches that have led to significant breakthroughs regarding recovery after an acquired brain injury (ABI). Those approaches include environmental enrichment, exercise, and task-specific training. Most task-specific or goal-oriented training involves coordination between cognitive and motor functions, as do many activities of daily living which is what makes dual-task training so important. Additionally, Mala and Rasmussen (2017) point out that:

> Monotherapies fail to encompass the complexity of changes following ABI. It is by now apparent that after brain injury, the brain is struggling to normalize with both pro- and anti-recovery processes taking place. Targeting only narrowly defined injury mechanisms may therefore not lead to notable improvements in the clinic, (p. 26).

Again this suggests the importance of utilizing a variety of therapeutic methods in order to maximize the recovery of someone who has sustained a brain injury due to the complexity of the organ.

A long-term study was done on young adults who had suffered from a TBI and were 1-9 years post-discharge. Catherine Foy (2014) performed the study and found that, “Clients with severe/very severe brain injury can attain a positive vocational outcome following intensive neurorehabilitation consisting of traditional therapies in addition to educational and VR,” (Foy, 2014, p. 533). This demonstrates that it is possible to make a recovery following an injury that is as complex as a TBI if the proper methodologies are used. Additionally, it suggests using a variety of methods to stimulate the mind and body is more effective in rehabilitative settings than monotherapies.

Methods

This paper is a systematic review of the available primary research regarding dual-task training and its effectiveness in a rehabilitative setting following damage or injury to the brain. The research considered for this study has been published within the past ten years. Many articles indicate that the research is in its infancy, but each article included in this study contributes a promising piece of information to support the efficacy of dual-task training on improving balance.

Purpose

This study aims to determine the relationship between cognitive and balance training in regard to how they stimulate the brain and directly improve one another. Following the establishment of this correlation, the study examines how dual-task training can significantly improve motor skills and the ability to perform activities of daily living. Since this is a systematic review, all information is derived from primary research, no experiment was done by the author of this paper.

Research Questions

- What is the correlation between performance on cognitive testing and performance on balance testing?
    - Research done by Kara Kaya and Ayse Zengin Alpozgen (2022) demonstrates the neural link between cognitive thinking and motor output that takes place in the dorsolateral prefrontal circuit in the prefrontal cortex.
- Has cognitive training been shown to enhance performance on balance testing and vice versa?

    - Lal et al. (2018), and Tam et al. (2022) both explain that physical activity has proven to improve cognitive ability, especially following a brain injury. Kaya and Alpozgen support this and take it a step further by explaining that exercise routines that demand balance more than aerobic capacity may be more effective in improving cognitive function. Also, while cognitive training has proven to be an important part of making a full recovery following a brain injury, the efficacy of cognitive monotherapies on improving balance is less clear.
- Is dual-task training an effective way to enhance both cognitive and balance performance?
    - Atas et al. (2022) explain that dual-task training is likely the most effective therapeutic method in decreasing fall-risk in those with balance impairments, however they were sustained. This is again supported by Woytowicz et al. (2017), which explains that a fundamental component of postural control during activities of daily living is the ability to dedicate cognitive resources to meet postural demands. Simply put, people need to be able to think clearly while simultaneously completing motor tasks on a daily basis, hence the importance of training this skill.

Research Design (Including Variables)

The research design is a systematic review of the primary literature that has been written about dual-task training, brain injury rehabilitation, and other balance training modalities. The systematic review includes peer-reviewed journal articles from EBSCOhost and PubMed databases. Of the considered journal articles, 14 were included in the systematic review, all of which were published within 10 years of the starting date of this research paper. Variables in the

primary research examined were the age of participants, existing medical conditions or lack thereof, and the type of training administered.

Instrumentation

Materials used were peer-reviewed primary research articles regarding balance training, cognitive testing, dual-task training, and other systematic reviews on the same subjects. Research articles written within ten years were considered for this systematic review. Several cognitive and balance testing modalities were used in the primary research studies, including the Balance Error Scoring System, the Berg Balance Scale, the Timed Up and Go Test, the 10-meter walk test, ImPACT testing, and Nelson's Speed of Movement test. Instruments required to administer these tests include a stopwatch, tape measurer, ruler, and computer software or a hard copy of ImPACT procedures and a place to record both survey and testing results. Examples of these tests can be found in Appendix A.

Population (Sample)

The population observed in the primary research considered for this systematic review was not limited to a specific demographic. Participants in studies ranged from young, athletic populations with no prior health considerations to older adults over the age of 65 that had neurological disorders such as Parkinson's disease. Other observed populations included people who had previously sustained a brain injury such as a concussion or were still suffering from concussion symptoms. The sample population was not limited to a specific gender or age group.

Data Collection

First-hand data was not collected during the systematic review. However, primary research sources were used to compose this systematic review, and their data will be compiled and analyzed, thus classifying this paper as a secondary research source. Of the articles

included, many use the Balance Error Scoring System as a way to quantify the participant's improvements throughout their training regiments. Some other performance tests were used, as discussed in the review of literature, such as Nelson's Speed of Movement Test. In articles that were written on populations that had sustained a head injury, the immediate post-concussion test was used to quantify performance and symptoms throughout the training regimen.

Data Analysis

Of the 14 articles included in the systematic review, 4 specifically addressed the older adult population (>65 years), 5 addressed the young adult to adult age range (approximately 18-40 years), 1 addressed children (<18 years), and 3 were systematic reviews. Both male and female participants were considered in these studies, however, the trend is that the majority of participants were male. Common methods for assessing balance and gait improvement following dual-task treatment in the older adult population included the Balance Error Scoring System, the Berg Balance Scale, the Timed Up and Go Test, and the 10-meter walk test. The adult, young adult, and child populations were more commonly tested using components of the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) to evaluate balance, gait, and cognitive performance whether a brain injury was sustained or not. Other tests include the Balance Error Scoring System, Sensory Organization Tests (SOT), verbal and visual memory and motor speed scores, and Nelson's Speed of Movement Test.

In studies that examined the effects of motor-cognitive dual-task training on their selected population, improvement was seen on all previously listed tests for each population. Randomized controlled trials compared control groups, which underwent standardized gait and balance training alone, with variable groups that received dual-task training. Although there were differences in the selected balance and gait training exercises as well as the selected cognitive

tasks between studies, all of them provided statistically significant results that were indicative of increased improvement in the ability to balance due to cognitive-motor dual-task training compared to balance training alone.

Systematic reviews that examined similar topics, such as the application of dual-task training following brain injury or to patients with neurological conditions such as Parkinson's disease reached similar conclusions. It is noted in almost all of the articles that the research is still in its infancy. Therefore, the most effective type of dual-task training for improving balance is still being examined, and it is likely that it will vary by population and condition, but the available research and data indicate that dual-task training holds promise to be an effective form of rehabilitation for those suffering from a brain injury or neurological damage.

Findings

Following a review of fourteen peer-reviewed journal articles published within the past ten years from EBSCOhost and PubMed databases, it is now possible to answer the research questions that have guided this systematic review. This paper was written with the purpose of exploring whether or not cognitive dual-task training can positively impact balance scores for individuals, specifically those who have experienced nerve damage. The overarching trend amongst the reviewed articles is that the research is still in its infancy, and therefore the most effective dual-task training paradigm for any specific population is still being studied. Despite this, the current research is suggestive of a neural link between cognitive and motor portions of the brain and shows promise that cognitive dual-task training can increase one's ability to balance and therefore decrease their fall risk during activities of daily living.

Research Questions/Data Analysis

The first research question was: “What is the correlation between performance on cognitive testing and performance on balance testing?” Kaya and Alpozgen (2022) explain the overlap between cognitive and motor portions of the brain in the dorsolateral prefrontal cortex. Furthermore, Riva et al. (2018) go into detail about another region of the brain, known as the basal ganglia, which is responsible for cognitive functions such as motor learning, including stimulus-response associations, as well as motor control which is an important aspect of successful balancing. This neurological overlap between cognitive and motor functions within the same regions of the brain is indicative of the relationship between the two and suggests that it is entirely possible for one to impact the other. This is further supported by the findings of Kaya and Alpozgen (2022) who show that balance-based exercises had a greater impact on verbal fluency, selective attention, and inhibitory control, which are all measures of cognitive strength, than aerobic exercise did.

The second research question was: “Has cognitive training shown to have a positive impact on balance testing and vice versa?” Referring to the previously discussed study by Kaya and Alpozgen (2022), it can be seen that balance training has a positive impact on cognitive performance. This is built upon by Lal et al. (2018), who completed a systematic review of randomized control trails, cohort studies, and pre-post studies regarding the impact of exercise on Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) scores in people who had experienced a mild traumatic brain injury. There was statistically significant data to demonstrate that physical activity reduced concussion symptoms and improved cognitive performance. Although it is noted in their conclusion that further research needs to be done to investigate varying intensities of exercise, different time points, and different durations following injury in order to have a full understanding of the relationship between physical activity and

cognitive improvements. Another noteworthy point from Lal and their colleagues is that it is known that cognitive training is an important aspect of making a full recovery following any sort of brain injury. However, the research about whether or not cognitive monotherapies without the addition of physical training can impact balance testing scores is unclear.

The final research question was: “Is dual-task training an effective way to enhance both cognitive and balance performance?” Atas et al. (2022) explain that dual-task training is likely the most effective therapeutic method in decreasing fall-risk in those with balance impairments. They came to this conclusion by using a pre-post-controlled study involving three groups: a control that performed single-task balance exercises, a group that performed simultaneous cognitive dual-task activities, and a group that performed successive cognitive dual-task activities. Groups two and three, which underwent the cognitive dual-task paradigms, showed the greatest statistical improvement between their pre and post-tests regarding balance scores. Cognitive tests, although a part of the training regiment, were not measured in this study. Woytowicz et al. (2017), explain that a fundamental component of postural control during activities of daily living is the ability to dedicate cognitive resources to meet postural demands. They reached this conclusion by using 2-back working memory tasks in two groups, one with and one without balance impairments. Their data was supportive of the concept that the coupling of cognitive and balance training is the most effective method for improving both traits, especially following a brain injury.

Conclusions

The current research, written within the past ten years, is indicative of a relationship between cognitive and motor control centers within the brain. These are two functions of the

neurological system that are often discussed separately, but due to the complexity of the brain and the extent of damage that can occur following a traumatic brain injury or development of a neurological disorder, it is important to consider them as a unit and train them accordingly. As mentioned, the research is still in its infancy, meaning that there are still plenty of variables left to be considered and examined. Some of these include: the demographic of patients, type of training to be included, frequency and duration of sessions, modality of injury, etc. Treatment of the brain is just as complex as the brain itself, which means it is likely that the most effective form of training will be different for each individual.

There are plenty of critiques to be made of the current research, a major one being the lack of research regarding the impact of cognitive monotherapies on balance performance. Although, due to the muscular demands of a balance or gait activity, it is likely that cognitive training that does not include stimulation of the muscular system would not be as effective as dual-task training or balance monotherapies on balance scores. Another critique, as mentioned, is simply the lack of controlled trials which could provide us with a wider variety of data and perhaps a clearer picture of the most effective training modalities. Nonetheless, the neurological link between these two traits has been demonstrated, as well as their importance in activities of daily living, which provides sound reasoning for more extensive research to take place.

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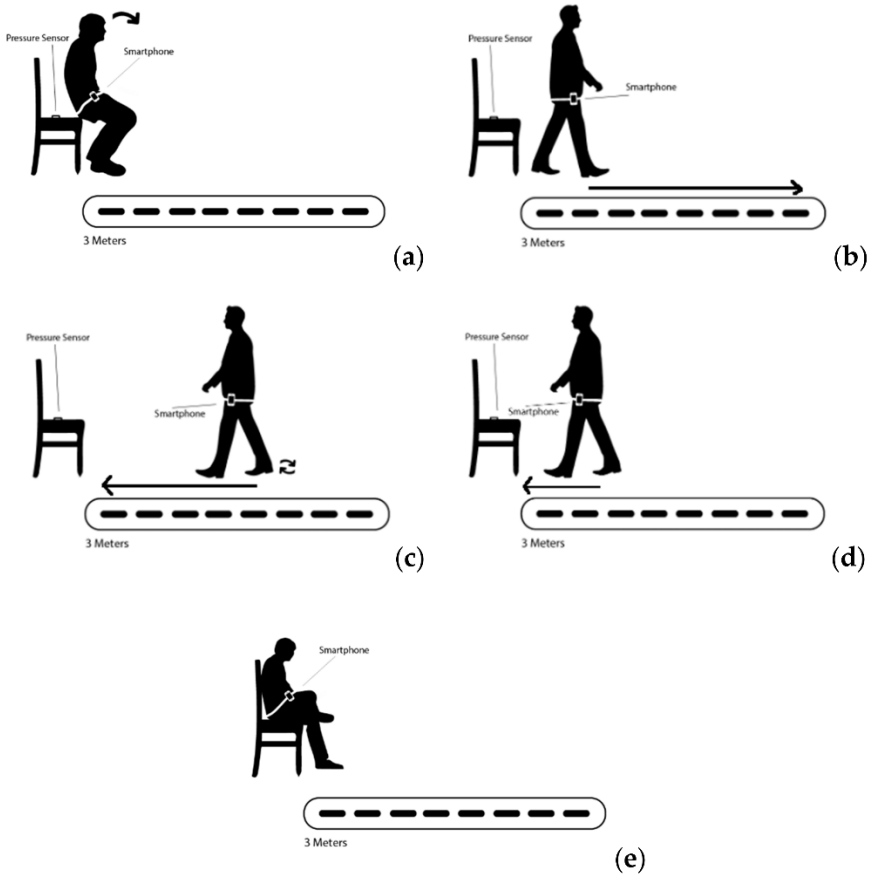
Appendix A



Timed Up-and-Go Test (Ponciano et al., 2020)

ImPACT APPLICATIONS, INC.

ImPACT Clinical Report

Sample Sam

Exam Type	Baseline	Post Injury 1	Post Injury 3	Post Injury 4
Age When Tested	26	26	26	26
Date Tested	2/2/19	5/19/19	5/27/19	6/1/19
Concussion In Last 6 Months	Yes	Yes	Yes	Yes
Exam Language	English	English	English	English
Test Version	3.10.0	3.10.0	3.10.0	3.10.0

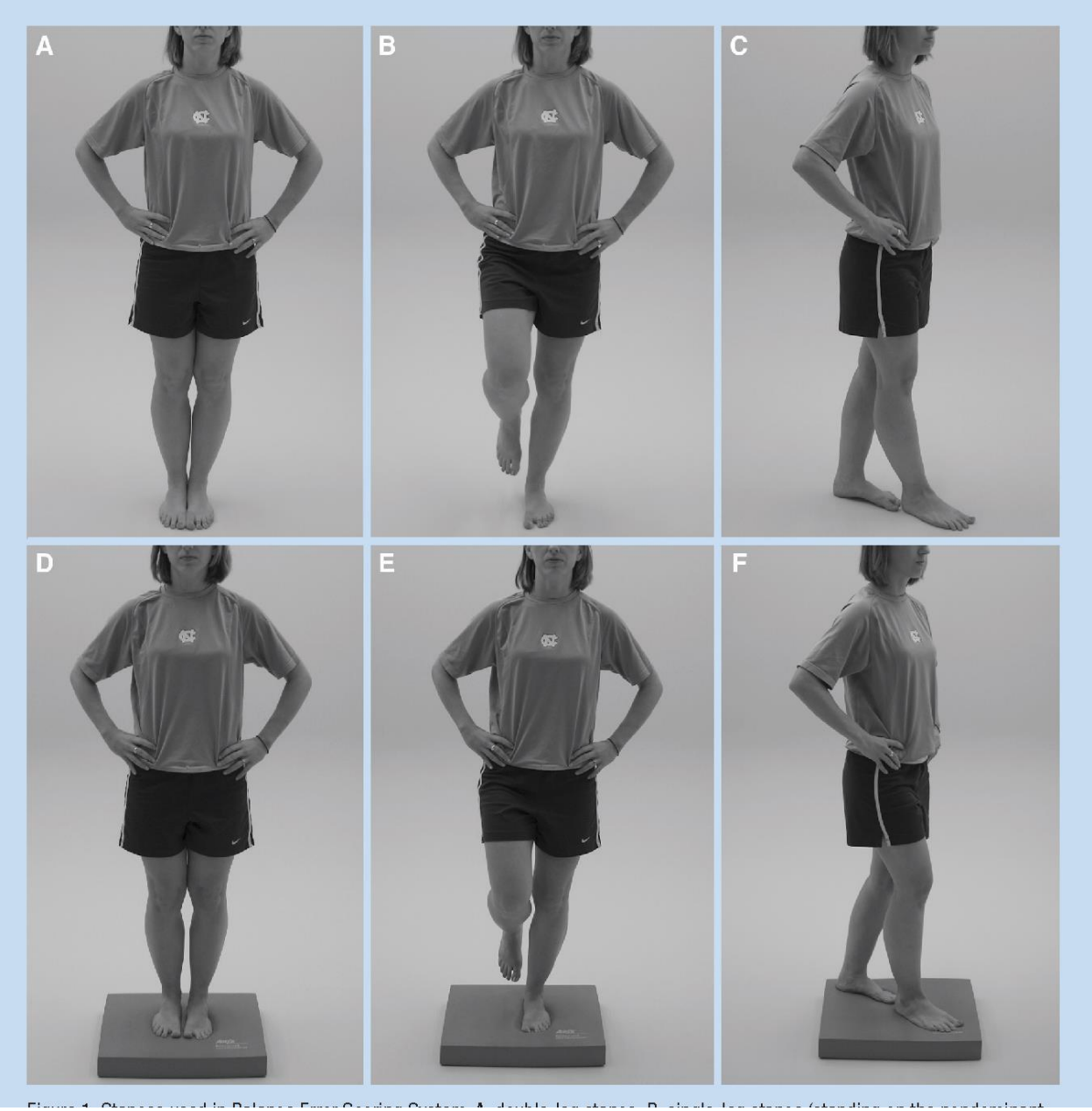
COMPOSITE SCORE

Memory composite (verbal)	98	94%	76	21%	86	56%	95	84%
Memory composite (visual)	98	98%	62	19%	75	48%	95	96%
Visual motor speed composite	50.42	92%	34.46	21%	46.26	76%	46.95	80%
Reaction time composite	0.47	96%	0.70	7%	0.56	59%	0.45	98%
Impulse control composite	1		1		1		1	
Total Symptom Score	3		29		12		2	
Cognitive Efficiency Index	0.94		0.99		0.99		0.92	

ImPACT testing clinical report (What is impact testing?: Impact applications, 2022)

lustration of the Nelson's speed of movement test: A – Starting position; B – End position

Nelson's Speed of Movement Test (Singh et al., 2009)



Balance Error Scoring System (Bell et al., 2011)