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The Effects of a Yoga Intervention on Reactive Balance in Older Adults

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THE EFFECTS OF A YOGA INTERVENTION ON REACTIVE BALANCE

IN OLDER ADULTS

by

Haley M. Hayes

A thesis submitted in partial fulfillment
of the requirements for the degree

of

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ABSTRACT

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by

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Utah State University, 2019

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Research into successful aging has shown that the ability to control balance is a key part of maintaining an independent lifestyle. Given the increased proportion of older adults in society, the development of effective strategies to promote successful aging are critical. One promising form of activity that could effectively sustain and/or improve balance in addition to other health markers is yoga. Although studies have been done showing yoga's benefits on mobility, mood and cognition the vast majority of these studies lack scientific rigor. The main purpose of this thesis project was to examine the efficacy of a 6-week yoga intervention in improving reactive balance in older adults. This study is one part of a larger intervention study that investigated changes in cognitive function and muscle strength in addition to balance. Thirteen older adults were randomized into a yoga intervention group (n=7) or a control group (n=6). Subjects in the yoga group participated in hour long classes, twice per week for six weeks. Each yoga class incorporate seated, standing and lying down poses along with breathwork and meditation. Subjects in the control group completed hour long sessions of computer-based cognitive training twice per week for six weeks. Reactive balance was tested using a custom lean and release device both before and after the intervention. Balance performance was measured as: (a) muscle onset time in the stepping leg, when a forward step was required to recover balance, and (b) stepping errors (i.e. taking a step when the leg was blocked). No statistically significant effects were noted between groups on response time ($p = 0.447$) nor error rate ($p = 0.622$). However, the low sample size likely compromises our ability to make definitive conclusions. This study is an early attempt to get very focused measures to evaluate yoga, using a balance task that emphasized heightened cognitive demand. With this study we were able to demonstrate the feasibility of using yoga as an intervention and provide insight for future studies looking at the potential effects of yoga on reactive balance in older adults.

(38 pages)

PUBLIC ABSTRACT

The Effect of a Yoga Intervention on Reactive Balance in Older Adults

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Research into successful aging has shown that the ability to control balance is a key part of maintaining an independent lifestyle. Given the increased proportion of older adults in society, the development of effective strategies to promote successful aging are critical. One promising form of activity that could effectively sustain and/or improve balance in addition to other health markers is yoga. Although studies have been done showing yoga's benefits on mobility, mood and cognition the vast majority of these studies lack scientific rigor. The main purpose of this thesis project was to examine the efficacy of a 6-week yoga intervention in improving reactive balance in older adults. This study is one part of a larger intervention study that investigated changes in cognitive function and muscle strength in addition to balance. Thirteen older adults were randomized into a yoga intervention group (7 participants) or a control group (6 participants). Subjects in the yoga group participated in hour long classes, twice per week for six weeks. Each yoga class incorporate seated, standing and lying down poses along with breathwork and meditation. Subjects in the control group completed hour long sessions of computer-based cognitive training twice per week for six weeks. Reactive balance was tested using a custom lean and release device both before and after the intervention. Balance performance was measured as: (a) muscle onset time in the

stepping leg, when a forward step was required to recover balance, and (b) stepping errors (i.e. taking a step when the leg was blocked). No differences were noted between groups on response time or error rate, however, it is likely that the low sample size compromises our ability to make definitive conclusions. This study is an early attempt to get very focused measures to evaluate yoga, using a balance task that emphasized heightened cognitive demand. With this study we were able to demonstrate the feasibility of using yoga as an intervention and provide insight for future studies looking at the potential effects of yoga on reactive balance in older adults.

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INTRODUCTION

Successful aging has drawn the attention of researchers for decades with the goal of studying ways adults can continue to enjoy life fully as they age. The term successful aging was first used by Robert J. Havighurst in 1961 when he stated the importance of developing a model that advises individuals how to get enjoyment and satisfaction in their later years (Havighurst, 1961). While the models for successful aging are diverse and continue to be updated, balance and cognitive function have emerged as key factors to sustain an active and independent lifestyle as one ages.

Despite the apparent ease with which we control upright stance, the control of balance is actually a complex task that becomes increasingly difficult for the aging adult (Anton et al., 2015; de Dieuleveult, Siemonsma, van Erp, & Brouwer, 2017). Research continues to reveal age-related changes that affect balance ability including reduced range of motion, diminished strength, and reduced cutaneous sensation from the feet (Maki & McIlroy, 2006). The capacity to react in a timely and accurate manner to a postural perturbation also decreases with age as shown by the delayed and inappropriate balance reactions of older adults compared to younger adults (Maki & McIlroy, 2006). Recovering balance following unexpected postural perturbation is especially difficult for older individuals when a new base of support needs to be established by reaching to a handrail or when stepping around obstacles (Brown, Shumway-Cook & Woollacott, 1999; Maki, McIlroy, & Fernie, 2003). This ‘change-in-support’ strategy demands involvement from the cerebral cortex (i.e. higher brain function) to navigate the arms/legs around environmental constraints to acquire a new suitable support base (Jacobs &

Horak, 2007), which may partly explain the correlation between cognitive decline and fall prevalence (Ambrose, Paul, & Hausdorff, 2013).

When recovering from a perturbation, an individual needs to be able to selectively allocate attention and inhibit unwanted responses, both processes demonstrating the need for higher brain function in balance recovery (Liu-Ambrose, Nagamatsu, Hsu, & Bolandzadeh, 2013) and dispelling the previously held belief that balance control was solely managed by subcortical reflexes (Magnus, 1926). These higher brain processes contribute to fall recovery in two ways: by descending pre-selection of appropriate responses based on the environment, and during longer latency responses that modify corrective balance reactions online (Jacobs & Horak, 2007). Studies have demonstrated a further reduction in postural stability under dual-task task conditions suggesting cognitive decline may further impair a person’s ability to react appropriately when engaging in two tasks simultaneously (Woollacott & Shumway-Cook, 2002; Shumway-Cook, Woollacott, Kerns, & Baldwin, 1997). Combined with reduced animal preparations that reveal a clear cortical role in shaping postural reactions (Beloozerova et al., 2003) and the studies showing how cognitive abilities are predictive of future falls (Monterro-Odasso, Verghese, Beauchet & Hausdorff, 2012), there is now strong evidence that higher brain processes are necessary for optimal control of balance.

Like balance, cognitive function is also susceptible to age-related decline (de Dieuleveult et al., 2017). Researchers are showing that there is a correlation between cognitive impairment and falls and that even subtle cognitive decline has been shown to result in an increase in fall risk (Muir, Gopaul & Montero-Odasso, 2012). Although the link between fall prevalence and cognitive decline is now acknowledged, there remains no mechanistic understanding of how higher brain processes actually contribute to balance (Bolton, 2015; Jacobs, 2014). Concepts such as response inhibition and the ability to filter out irrelevant stimuli are potentially critical when considering our ability to avoid falls (Liu-Ambrose et al., 2013), however these issues await experimental scrutiny. Studies continue to reveal the importance of improving cognitive function along with physically strengthening the body to reduce falls in older adults (Liu-Ambrose et al., 2013; Monterro-Odasso et al., 2012), which suggests that the optimal strategy to encourage a mobile, independent lifestyle as we age must incorporate both physical and cognitive capacities.

Given the increased proportion of older adults in society, the development of effective strategies to promote successful aging are critical. As previously stated, current research is revealing the cortical influence on reactive balance showing the importance of engaging in activities that challenge the physical as well as the cognitive systems. Popular senior activities such as walking, water aerobics or weight lifting focus solely on the physical side of well-being, without directly emphasizing cognitive improvements. Also lacking is the inclusion of strength work, flexibility and balance training in one all-encompassing exercise modality. One particularly promising intervention is yoga because it focuses on the mind and the body by incorporating all the aspects of a physical exercise with the addition of mindfulness therefore improving balance and cognitive function simultaneously.

Yoga is an ancient form of exercise stemming from Indian philosophy that consists of breath work, physical poses and meditation connecting the mind to the body.

Yoga has become a popular complementary and alternative medicine to help offset the effects of aging. The results of a 2012 United States National Health Interview Survey found that about 31 million adults have tried yoga and approximately 21 million have practiced yoga in the previous 12 months (Cramer et al., 2016). Yoga offers a number of advantages as a physical intervention for older adults in its ability to be individualized, it offers a low risk of injury and is highly accessible (Jeter, Nkodo, Moonaz, & Dagnelie, 2014).

The mind-body connection, foundational to yoga, has made it a compelling research subject. Studies have demonstrated yoga's positive effects on balance, mobility and cognition. In studies involving healthy community-dwelling individuals, yoga was shown to improve postural control, gait speed and mobility (Kelley, Aaron, Hynds, Machado, & Wolff, 2014; Tiedemann, O'Rouke, Sesto, & Sherrington, 2013). When looking at cognitive-motor interference (CMI), yoga practitioners were significantly better at allocating attention during the dual-task trials suggesting that a yoga practice can improve dynamic balance and executive cognitive function by reducing CMI (Subramaniam & Bhatt, 2017). It has also been shown that a single yoga session improved cognitive performance compared to a single aerobic exercise session (Gothe, Pontifex, Hillman, & McAuley, 2013). The cognitive test result showed that after the yoga practice reaction times were shorter and performance was improved in a task which required working memory and response inhibition. No improved effects were seen after the aerobic session suggesting that a solely physical exercise doesn't provide the same cognitive benefits as yoga. The single yoga session incorporated exercises for the mind and the body that included regulated breathing, physical poses and meditation (Gothe et al., 2013).

Yoga has a lot of potential, but the vast majority of these studies lack scientific rigor, such as a lack of proper controls, insensitive outcome measures, and very low sample sizes (Jeter et al., 2014; Walsh & Shapiro, 2006). Yoga possesses many favorable characteristics including its ability to target flexibility, strength, balance and mental focus. Because of yoga's multifaceted approach it warrants being studied as an intervention for improving reactive balance and adding scientific rigor to a promising potential intervention that will foster successful aging.

The purpose of this study was to assess if a yoga intervention could improve the efficacy of the reactive balance response to avoid a fall in an older community dwelling population. Our prediction was that these improved responses would manifest as faster muscle onsets in a stepping leg to recover balance, and more appropriate limb reactions for a particular response environment (i.e. avoid stepping into a leg block and grasping a handrail as required). We hypothesized that 6 weeks of a yoga intervention would result in more effective balance reactions in complex, choice-demanding environments compared with a sedentary control group.

METHODOLOGY

Participants

Thirteen community dwelling older adults, age 60+, were recruited into the study. Twelve subjects, 74.6 (+/- 4.7) years of age, completed the study. The yoga group initially had 7 participants (n=7), 4 females and 3 males. One participant (ID #8) did not want to continue after the second yoga class, and another participant (ID #13) was unable to complete the required blocks of pre-testing. One yoga participant (ID #1) completed the study, but her EMG signal was unusable for analysis, therefore only her error rate data was included. Therefore, the yoga group EMG data comprised 2 males and 3 females (n=5). The control group consisted of 3 females and 3 males (n=6). All subjects from the control group completed the study and testing. The only exception is that for one participant (ID #3) the handle force sensor was not working during post testing and will not be included in the handle contact time data (a secondary measure described later).

Participants were recruited through the Cache County Senior Community newsletter, the Summer Citizens program at Utah State University, local church and community groups, fliers and postings. Participants were excluded if they (a) had a history of neurologic or motor impairment due to illness or injury, (b) had practiced yoga or tai chi in the last year, (c) were unable to stand unassisted for 2 minutes, (d) had serious visual impairments, (e) had uncontrolled high blood pressure, and/or (f) severe hypotension. Prospective participants were screened prior to enrollment in the study using a questionnaire (Adult Health History Form) and an established measure of cognitive function (Montreal Cognitive Assessment, MOCA). For the MOCA, the administrator of the test read the screening instructions to the participant for each of the 11 subsections and the participant provided both written and verbal responses. The test was scored out of a possible 30 points, and participants with a score less than 20 were excluded. All participants scored above 20. In order to be included in the study, participants had to be able and willing to attend six weeks of group-based yoga classes that required sitting, stretching and breathing exercises (*See Appendix for examples*). Eligible participants completed the informed consent prior to testing.

Sample size had been estimated using G-Power software (Beck, 2013). A moderate effect size was used based on similar studies (Gothe, Kramer, & McAuley, 2014; Subramaniam & Bhatt, 2017). Alpha was set at 0.05 and power at 0.80. Using this moderate effect size of f = .30 a sample size of 24 was determined.

Experimental Design

Participants were randomly assigned into either the *control intervention* or the *yoga intervention*. The one constraint we did put on the randomization was to try and keep the gender constant between the groups. Pre and post intervention testing was done at the Utah State University Perception-Action laboratory to assess balance ability on one day and then cognitive function and strength on a separate day. (Note: cognitive/strength testing was part of a separate study not directly related to the present thesis, therefore subsequent descriptions will focus entirely on reactive balance testing). The study timeline consisted of (1) Pre-testing, (2) Intervention (either 6 weeks of yoga practice or control) followed by (3) Post-testing.

Yoga Intervention: Participants in the yoga group attended a six-week Hatha yoga intervention. Group classes lasted one hour and were held twice a week on the main campus of Utah State University. The classes were led by a RYT-200 certified yoga instructor (Registered Yoga Teacher at the 200-hour level). Each class began with 10 minutes of active breath work, followed by 40 minutes of physical poses and the last 10 minutes of class ended with a guided meditation. Participants were instructed to listen to their bodies and not go beyond their physical limitations. Chairs, blocks and straps were available as needed, and the instructors demonstrated how to modify poses for those individuals unable to perform a given posture/exercise (See Appendix A). Attendance was kept ensuring that each participant attended at least twice a week for six weeks.

Control group: Participants in the control group performed six-weeks of computer-based cognitive training exercises. The training was conducted using a comprehensive brain fitness training program known as *Lumosity*® which employs a variety of computer games to challenge memory, attention and problem-solving ability. Participants trained twice per week for approximately one hour on a computer located within the Young Education Technology Center (YETC), supervised by a research assistant. The purpose of this control group was to account for weekly contact time with trainers and to engage individuals in some form of cognitive training without physical activity. Attendance was kept ensuring that each participant attended at least twice a week for six weeks. *Note: Lumosity® is available online for registration therefore the research staff arranged this for each control participant.*

Outcome Measures

Reactive balance was tested using a custom-made 'lean and release' cable system to impose unpredictable forward perturbations. The lean and release device has been successfully used in healthy adult populations as well as in clinical populations to assess reactive balance (Lakhani, Mansfield, Inness, & McIlroy, 2011a, 2011b; Mansfield et al., 2011). Some aspects of the perturbation were predictable, such as the direction and amplitude of perturbation, but the exact onset of the cable release was unpredictable. **Figure 1** depicts an example of the lean and release (i.e. reactive balance) test.

Figure 1. Lean and Release

This figure depicts a lean and release system. The response environment was altered to provide a handrail and/or impose a leg block. This allowed us to investigate how quickly and efficiently a participant could adapt their balance reactions to match the movement options afforded by the environment.

Participants were placed in a harness that was connected by cables to the wall behind them. They were instructed to lean forward in a standing position at the start of each trial. In one trial version, the participants had a block placed in front of their legs so that when the harness released from the wall, they were prevented from taking a forward step and instead forced to grab a wall-mounted handrail. In another trial version, the block was not present, therefore allowing a forward step to recover balance after the cable released. The participant wore special liquid crystal goggles (Translucent Technologies Inc. Toronto, ON, Canada) that occluded vision prior to the start of each trial to ensure they did not know which environment they were in until the goggles opened. A safety cable attached to the harness would catch the person if they failed to make the correct response based on the demands of the environment. There were also safety guards surrounding the area to ensure minimal risk of injury.

The setup of this experiment was such that the participant had to produce a rapid response to the environment they were placed in. The harness would release from the wall very shortly after the goggles opened; either 200 milliseconds, 400 milliseconds or 600 milliseconds. The varying and unpredictable times delays between when the goggles opened and the harness was released, allowed us to manipulate the duration of visual access to the environment before participants were required to react. The participant was first trained on the task until comfortable, and then the data collection portion of the task consisted of 4 blocks of 28 trials each. The participants had approximately 2-5 minutes of rest between each block and were provided a chair and water. The frequency of the reactive balance task was adjusted so that 70 percent of the time the participant was subjected to one condition, while only seeing the other condition 30 percent of the time. This primed the subject to develop an automated response based on the environment they were anticipating, and then had to suppress that response in order to make a correct choice when the other environment was present. The step condition was more frequent to promote prepotent motor activity, a prerequisite for testing response inhibition (Wessel, 2018). Electromyography (EMG) electrodes were placed on the Tibialis Anterior (TA) of both legs and the ground was placed on the Olecranon process of the right arm.

Two main outcome measures were proposed to analyze the data from the reactive balance task: (a) response time in the muscle activation of the stepping leg, and (b) error rate (i.e. failing to suppress a step when the leg block was present). Postural response time was measured by recording the muscle onset latencies of muscles in the limbs used to generate a step. Specifically, the Tibialis Anterior (TA), which acts to dorsiflex the ankle, was used to evaluate stepping activity in the leg. In previous studies, the balance recovery task has been assessed using clinical measures, therefore there is not any current reliability literature on using muscle onset time to assess this specific balance reaction task. To detect stepping errors, the leg block was fitted with force sensors, and foot switches were used to help detect unloading of the stepping leg. A researcher also kept a record of any stepping or reaching reactions via careful observation. A response error was originally defined as taking a step when the leg block was present. Thus, error rate was determined by the number of collisions with the leg block or inappropriate steps detected by footswitches. Given unexpected technical difficulties with using external force sensors to detect step errors, we instead relied upon experimenter observations for trials where steps occurred in the presence of a leg block. A follow-up measure, the movement time to grasp the handle, was measured (determined by force sensors on the handle) to assess the arm response during reach trials. The rationale for adding this secondary measure to the study was based on findings by Mansfield et al. (2010) where participants were able to grasp onto the safety handle faster after training with postural perturbations. Based upon these findings, we predicted that yoga participants would become faster at reaching the handle following the intervention. These outcome measures together provided an overall picture of the effectiveness of an individual’s balance response and determined how quickly they could revise balance reactions to suit a given response environment.

<u>Statistical Analysis</u>

A 2x2 mixed model ANOVA with time and delay (pre-test versus post-test) as the within-subjects factor and training condition (yoga versus control) as the between-subjects factor was used to test each variable: (a) muscle onset time of the Tibialis Anterior (b) number of response errors. Tukey's post-hoc comparisons were planned to follow up on any significant main effects or interactions. An alpha level of .05 was used for all statistical tests.

RESULTS

An Independent T-test indicated that there was no statistical significance in the MOCA scores (Figure 2; $t = -1.08$, $df = 9.00$, $p < 0.310$, $d = -0.651$) between the control group ($M = 27.2$, $SD = 2.56$) and the yoga group ($M = 25.8$, $SD = 1.30$).

MOCA (Montreal Cognitive Assessment)

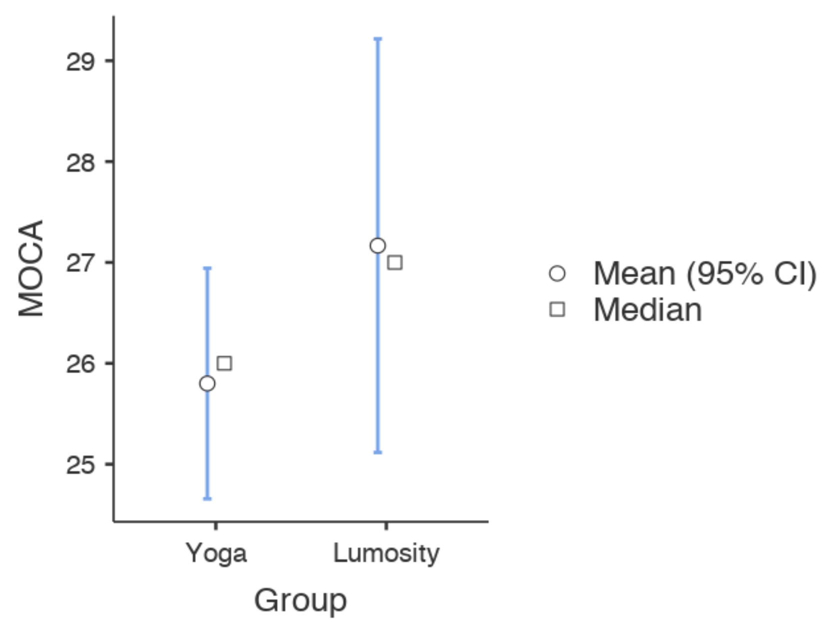

Figure 2. MOCA scores for the yoga and control groups.

<u>Response Time</u>

The results failed to reveal any statistically significant improvements (Figure 3; $F = 0.639$, $p = 0.447$, $\eta^2 = 0.074$, $SE = 0.0457$) in the muscle onset time of the Tibialis Anterior in the stepping leg between the yoga group (0.262 seconds +/- 0.069) and the control group (0.297 seconds +/- 0.104). The main effect of time was also non-significant ($F = 0.0023$, $p = 0.962$, $\eta^2 = 0.000$). The individual muscle onset times of the Tibialis Anterior are listed in table 1 along with the group averages at pre-testing and post-testing.

Time ✻ Group

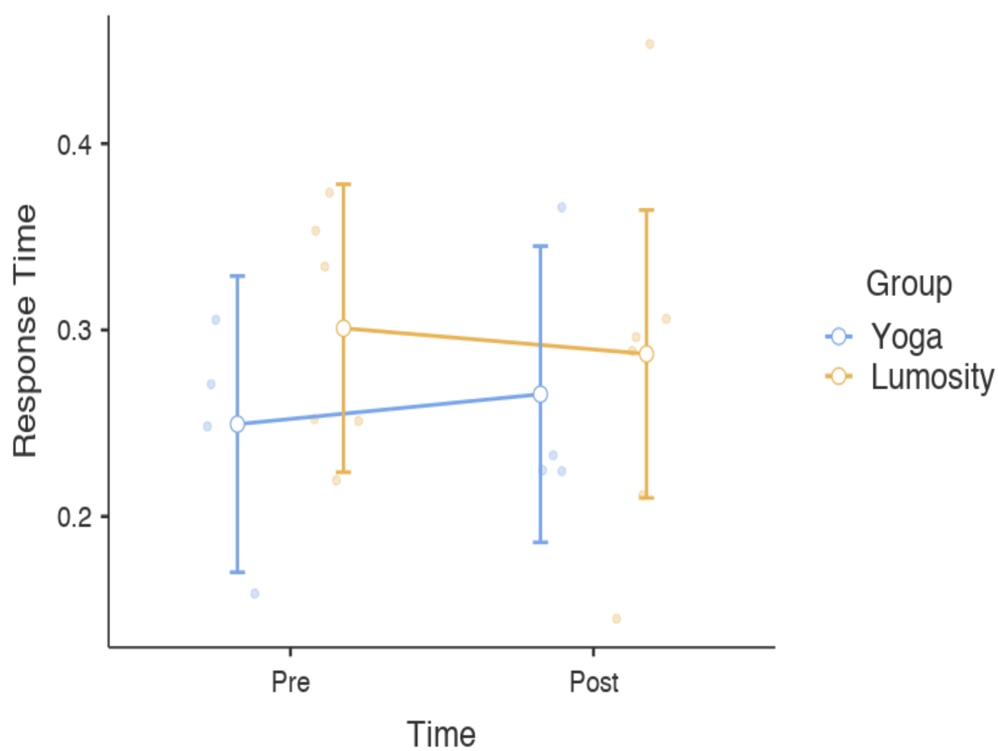

Figure 3. Response time (in seconds) of the TA between groups for pre-test and post-test. Faded dots represent individual data points. Error bars: 95% CI

Group	Subject	PRE	POST		PRE AVG	POST AVG
Yoga	2	0.305	0.224		0.2455	0.26125
Yoga	4	0.158	0.232			
Yoga	9	0.271	0.365			
Yoga	11	0.248	0.224			
Lumosity	3	0.252	0.305		0.2972	0.2835
Lumosity	5	0.373	0.453			
Lumosity	6	0.334	0.288			
Lumosity	7	0.219	0.145			
Lumosity	10	0.353	0.296			
Lumosity	12	0.251	0.211			

Table 1. Individual TA muscle onset time (in seconds) and group averages at pre-testing and post-testing.

Error Rate

The results did not show any statistically significant improvements in error rate between the yoga group and the control group ($F = 0.260$, $p = 0.622$, $\eta^2 = 0.028$, $SE = 5.06$). The main effect of time was also non-significant ($F = 1.110$, $p = 0.319$, $\eta^2 = 0.110$). Initial inspection of Figure 4 suggests a possible slight trend towards improvement in error rate for both groups, particularly in the yoga group. However, from Table 2 (below) closer inspection reveals that one participant in particular (Subject 9) appears to drive much of this effect (and contributes to the large variability between individuals in the group).

Time ✻ Group

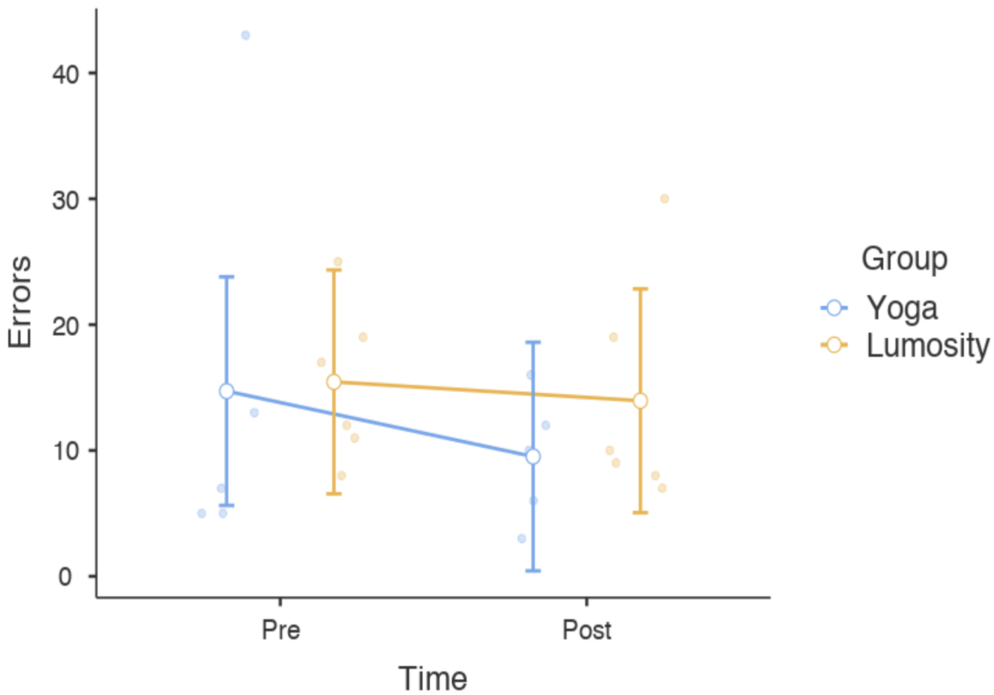

Figure 4. Error rate between groups for pre-test and post-test. Faded dots represent individual data points. Error bars: 95% CI

Group	Subject	PRE	POST	PRE AVG	POST AVG
Yoga	1	5	6	14.6	9.4
Yoga	2	7	3		
Yoga	4	5	12		
Yoga	9	43	16		
Yoga	11	13	10		
Lumosity	3	17	30	15.333	13.833
Lumosity	5	25	19		
Lumosity	6	11	10		
Lumosity	7	19	8		
Lumosity	10	8	7		
Lumosity	12	12	9		

Table 2: Individual number of errors and group averages at pre-testing and post-testing. Errors are the total number of step errors per test session.

Time to Handle

The results did not show any statistically significant improvement in handle contact time between the yoga group and the control group (F = 0.0350, p = 0.857, η^2 = 0.005, SE = 0.0667). The main effect was non-significant (F = 1.84, p = 0.217, η^2 = 0.208).

Time ✻ Group

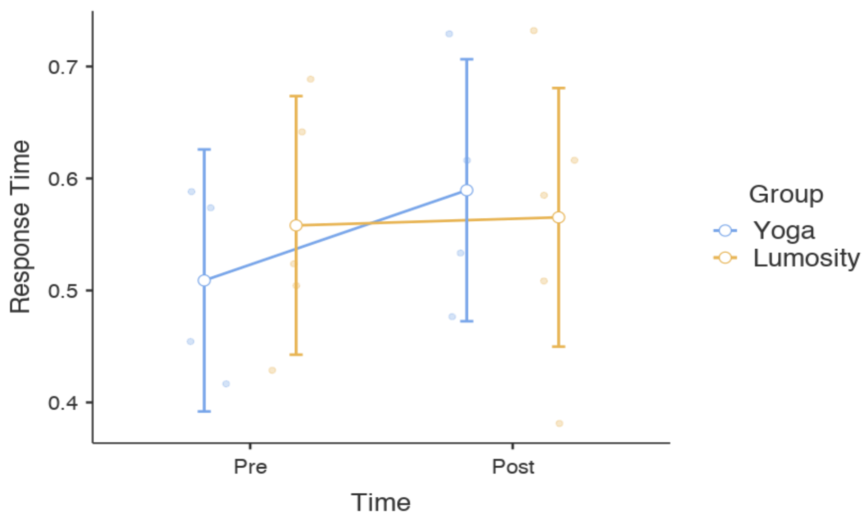

Figure 5. Time to handle contact (in seconds) between groups for pre-test and post-test. Faded dots represent individual data points. Error bars: 95% CI

Group	Subject	PRE	POST	PRE AVG	POST AVG
Yoga	2	0.588	0.729	0.50775	0.5885
Yoga	4	0.416	0.616		
Yoga	9	0.454	0.533		
Yoga	11	0.573	0.476		
Lumosity	5	0.688	0.732	0.5568	0.5644
Lumosity	6	0.641	0.585		
Lumosity	7	0.428	0.381		
Lumosity	10	0.523	0.616		
Lumosity	12	0.504	0.508		

Table 3. Individual average time to handle contact (in seconds) and group averages for pre-testing and post-testing.

DISCUSSION

Previous studies have used clinical assessments (i.e., Timed-Up and Go test and the Berg Balance Scale) of balance to determine the effects of a yoga intervention on balance. Statistically significant improvements at post testing on the Timed-Up and Go test (Kelley, Aaron, Hynds, Machado, & Wolff, 2014) and the Berg Balance Scale (Zettergren, Lubeski, & Viverito, 2011) suggest yoga's ability to improve balance in older adults. While these past measures reveal a positive impact of yoga on unperturbed balance control, they provide little insight into how upright posture is maintained when someone encounters an external threat to stability such as tripping on an obstacle or getting jostled on a crowded bus. Responding to unexpected balance perturbations, particularly in complex and cluttered environments, represents a heightened challenge that may not be sufficiently assessed in some of these aforementioned unperturbed balance tasks. Indeed, taxing our ability to recover balance in such a complex environment is perhaps the only means for truly exposing how traditional 'cognitive' functions impact our resistance to falls. For this study, testing of reactive balance in a choice demanding environment was chosen to more closely simulate compensatory reactions that occur when experiencing a perturbation in a real-world scenario (Maki & McIlroy, 2006). The current study measured the effects of a yoga intervention on reactive balance using sensitive measurements (i.e. surface muscle recordings and external force sensors) to determine if response time and error rate were improved. Because of the small sample size, no definitive conclusions could be drawn, yet insightful trends did emerge that may inform future research.

Overall, we predicted that yoga training would result in more effective balance recovery responses, assessed in terms of how quickly responses were made and if they were appropriate for a particular context (e.g. avoiding a step if a leg block was present). More specifically, we hypothesized that balance recovery steps would be faster following yoga training as measured by muscle onset in the tibialis anterior of the stepping leg compared with the control following a 6-week intervention. We also hypothesized that following yoga training balance recovery actions would have fewer errors as measured by taking a step in the presence of a leg block.

Our results show that there was no statistical improvement in muscle onset times in the yoga group nor the control group following the intervention. A potential explanation for the lack in improvement could be due to the chosen testing approach. In previous studies using EMG to measure improvement in response time the participants did not have the additional challenge of being placed in a choice demanding environment, instead they were aware of which recovery action to take before the perturbation occurred. For example, in a study that found statistically significant improvements in TA response time following Tai Chi training the testing protocol had subjects walk across a force plate that suddenly moved (Gatts & Woollacott, 2006). In our study, the participants were aware that choosing the correct recovery option afforded to them was being tested. It is possible that the participants prioritized making the correct decision over responding quickly, which means that the speed of step onset may fail to accurately capture improvement in this specific task. In this sense, delaying a response to allow appraisal of the visual scene may reflect an adaptive strategy. The design of the study to include choice in the balance recovery task may have contributed to the high variability of the EMG data compared to studies that did not include choice-demanding environments.

Our results show that there was no statistical improvement in error rate in the yoga group nor the control following the intervention. We expected the error rate to decrease in the yoga group due to the active awareness and attention practiced in yoga. Yoga as a practice focuses on mindfulness and has been shown to improve response accuracy during dynamic balance testing (Subramaniam & Bhatt, 2017) and cognitive function tests (Gothe, Kramer, & McAuley, 2014). The data suggests a possible trend in the error rate decreasing in both the yoga group and control group following the intervention, but the small sample size and high variability within the groups obscures any legitimate conclusions.

The response time to grasp the handle did not show statistically significant improvement in the yoga group nor the control group following the intervention. Surprisingly, the data indicates a trend in the opposite direction (i.e. time to handle becoming slower in both groups at post testing). In the study looking at the efficacy of a perturbation-based intervention compared to a stretching control group, the perturbation group managed to grasp the handrail more quickly than the control group following training (Mansfield, Peters, Liu & Makei, 2010). From these past results we originally speculated that our participants may become faster at reaching the handle when perturbed following their training. However, if anything, our participants showed a tendency to delay movements. In the Mansfield study, the intervention group was trained to grasp the handle quickly to recover balance without any need to ever suppress a compensatory arm movement. One possible explanation for the trend towards a longer contact time in both groups is that neither group were specifically trained on speed and perhaps the participants were prioritizing making the correct response over time to grasp the handle. This speculation is consistent with the earlier suggestion that participants may strategically delay responding to favor a correct response over a fast one.

Methodological considerations

The small sample size limits the ability to draw any definitive conclusions from the present study. The Summer Citizens program and the local community were targeted for recruitment into the study. Flyers were included in the 750 Summer Citizen welcome packets. To recruit from the local community small presentations were done at the Senior Community Center and 500 flyers were placed on doors in the local 55+ active adult communities. We found that the prospect of being randomized into a control group limited people's interest. Individuals interested in the study would state that they wanted to be in the yoga group and withdrew when explained that randomization would determine placement.

Mechanical issues with the reactive balance testing lead to a change in the post testing protocol for three subjects. Due to a wiring issue the release of the magnet had to be done manually. This occurred for the post testing of three yoga participants. The remaining yoga participant and the 6 Lumosity participants were post tested with the magnet releasing electronically. While this would not directly affect response onsets which were time-locked to the perturbation itself, this would have introduced more variability into how long participants had visual access to the leg block/handle prior to a perturbation. It is presently unclear what impact this may have had on our results, however it almost certainly added another source of noise to an already variable data set.

A potential confounding factor is that the groups were not matched physically at post testing and may not have been equal physically and cognitively at baseline. Before pre-testing the participants filled out a health history form that included any injuries. The control group consisted of 6 participants with no recorded injuries. The yoga group originally had 7 participants. At post-testing the yoga group consisted of 5 participants, 2 with recorded injuries. One participant had a fused ankle and during the six-week intervention sustained a knee injury outside of class to his stepping leg. The participant was cleared by his doctor for activity but required to wear a brace or tape the injured knee. A second yoga participant 3 years previous had fallen off a cliff resulting in nerve pain and limited spinal mobility. Another yoga participant had Type I diabetes. The cognitive assessment suggests that the groups were not well matched at baseline. Specifically, the control group had higher MOCA scores which may indicate they were higher functioning cognitively than the yoga group.

Finally, response time in a choice demanding environment may not be the best predictor of the balance improvements attained through a yoga intervention. Yoga as a practice does not focus on fast movements, instead the practitioner is encouraged to focus on deliberate, mindful movements. Consequently, any gains from yoga may not be specifically revealed through explosive movements when recovering balance.

Future Directions

While the present study posed numerous challenges, useful insights have emerged to guide future research. The fact that stepping and reaching reactions did not become faster with training (and may have even been delayed) was an unexpected result. Although speculative at present, this may indicate that the participants learned to strategically delay their responses until a choice could be made more effectively. Future studies should adopt more sensitive metrics to capture adaptations that may occur in a balance recovery task such as the one presently used (i.e. a task that emphasizes both speed and accuracy to avoid a fall). Also, in terms of assessing the impact of yoga on balance, tests that measure different aspects of balance should be included. For example, techniques such as Computerized Dynamic Posturography could provide insight into standing balance, and the ability to reweight sensory inputs to control postural sway (e.g. ability to remain stable when vision is removed). Changes in the ability to maintain unperturbed standing balance may ultimately be more representative of adaptations from yoga, and would represent an important area of improvement for resisting future falls in older adults.

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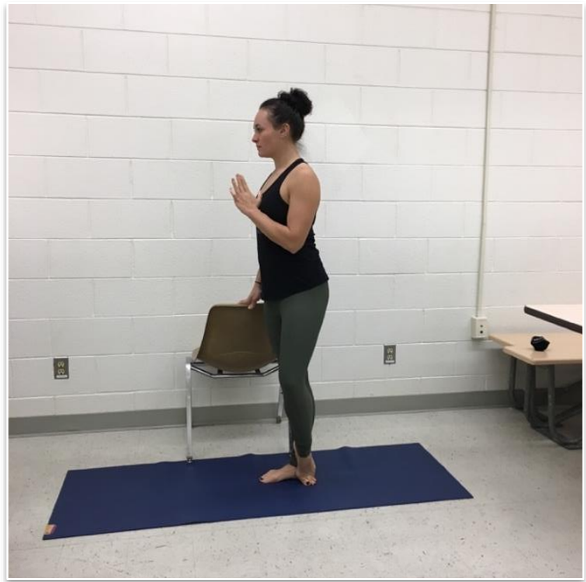
APPENDICES

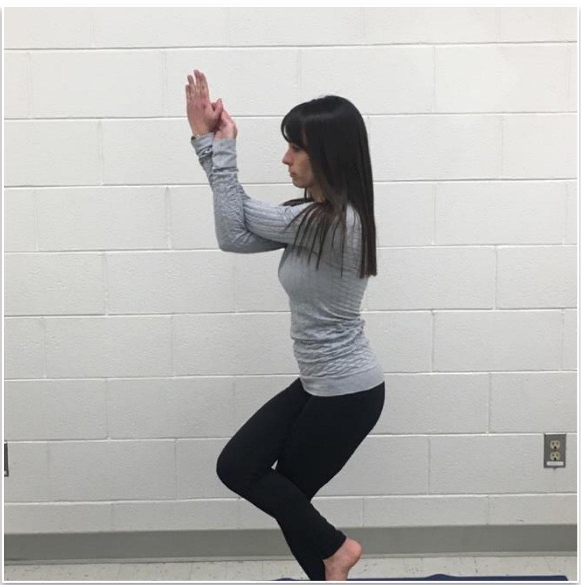
Appendix A. Example Yoga Poses Used in the Study

Tree Pose

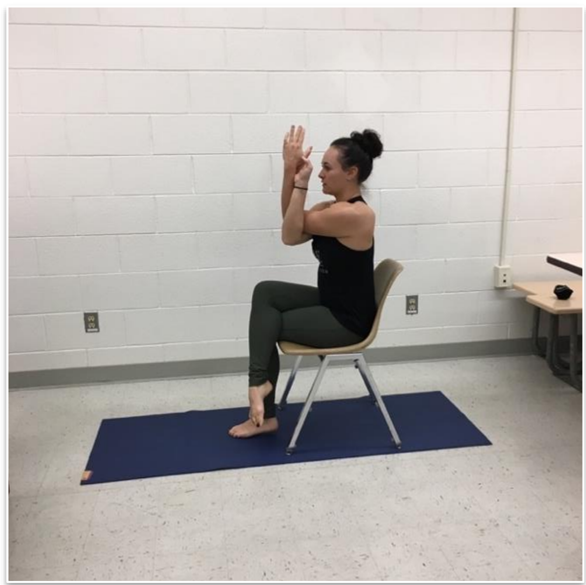
Tree Pose with chair



Eagle Pose



Eagle Pose seated

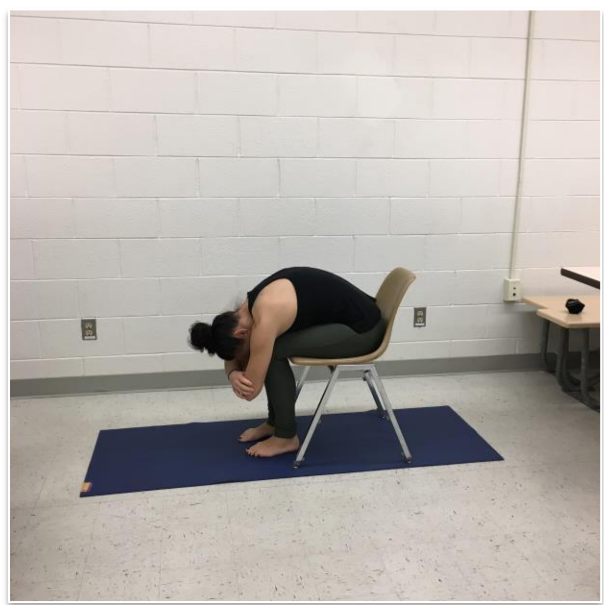


Dancer Pose

Dancer Pose with chair

Mountain Pose

Forward Fold seated



Appendix B. Sample Yoga Class Structure

10 minutes breath work

- Ujjayi breath- active, deep breathing

40 minutes physical poses

- Standing poses
- Standing balancing poses
- Seated poses
- Supine poses

10 minutes guided relaxation

- Guided meditation
- Savasana