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# Dynamic Stability on Land and in Waist-Deep Water: Comparison Between Young and Middle Aged Adults

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# DYNAMIC STABILITY ON LAND AND IN WAIST-DEEP WATER: COMPARISON BETWEEN YOUNG AND MIDDLE AGED ADULTS

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## Abstract

The purpose of this study was to compare dynamic stability on land and in water, between young and middle-aged adults performing plyometric exercises. Twenty adults were asked to volunteer: Young = 24.40 ± 2.63 years, n = 10 and middle-aged = 46.80 ± 3.05 years, n = 10. Participants performed three plyometric exercises (countermovement jump, squat jump, and drop landing) on land and in waist-deep water. Dynamic stability was assessed during landing for each exercise using a time to stabilization (TTS) paradigm. Data were collected via a waterproof force plate positioned on an adjustable-depth pool floor and analyzed with a 2 (age) X 2 (environment) x 3 (jump type) repeated measures ANOVA. Results revealed TTS was greater on land (1.45 ± 0.12s) than in water (1.35 ± 0.12s) for two jumps ($p = 0.01$). Across both age groups, dynamic stability was better in the water. This suggests that jump training in water may be beneficial for improving dynamic stability.

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## Introduction

Human balance is an essential element in producing gross motor functions such as walking, standing and sitting. According to Pollock, "human balance is a multidimensional concept, referring to the ability of a person not to fall" (2000). For one to achieve balance the person's line of gravity must lie within the base of support. There are many factors that influence a person's ability to maintain balance, a few of which are the height of the center of gravity, the size of the base of support, gender, age, physical activity level and previous balance training (Heyward & Gibson, 2014). Control of balance is dependent upon the coordination of sensory input from the visual, proprioception, and vestibular systems (Louder et al., 2014). If any of these systems are dysfunctional or uncoordinated, a person's balance may be compromised.

Four different types of balance have been described. For example, static balance is where there is no movement, dynamic balance includes movement, functional balance includes movement associated with everyday activities, and reactive balance describes the ability to recover from unexpected stimuli. Generally, balance plays an important role in mitigating the fall risk and subsequent injury in the elderly and is positively associated with improved performance and reduced risk of injury in athletic populations (Louder et al., 2014). All four types of balance are important in decreasing fall risk, however, the majority of the falls happen in a dynamic balance situation. Dynamic balance or dynamic stability can be defined as the inherent motor, sensory, and physical ability of a person to maintain, achieve or restore a specific state of dynamic balance and not to fall (Pollock et al., 2000). In other words, dynamic stability as is the ability to correct disturbances in balance (Liu & Heise, 2013). As mentioned earlier, dynamic stability is important in maintaining activities of daily living, functional mobility, and decrease the risk of falls.

All aspects of sensory function diminish with age, resulting in modest sensory changes in older patients. The decline in sensory functioning affects the ability to maintain correct balance after disturbances resulting in a decline in dynamic stability (Crenshaw & Grabiner, 2014; Wolfson, 2001). Older women who have several coexisting sensory difficulties combined with FOF (fear of falling) are particularly vulnerable to mobility decline. Avoidance of walking as a result of FOF is likely to be reinforced when multiple sensory difficulties hinder the reception of accurate information about the environment, resulting in an accelerated decline in walking ability (Viljanen et al., 2012). There is growing evidence that FOF may be less in aquatic than land environment and that improvement in static balance may be enhanced after aquatic balance training (Bressel et al., 2014).

When threats to balance from a decline in sensory functioning or other stimuli occur, rapid responses must be engaged to maintain postural stability and not fall. With aging, a slowed response to these threats decrease the chance of performing a correcting action in time to prevent a fall. Thus, the velocity at which high muscular forces can be generated, muscular power, may be the critical determinants to prevent a fall (Orr et al., 2006). Power training in older adults has found to be more effective in maintaining functionality and reducing fall risk than muscular strength or muscular endurance training. Research by Rhonda Orr et al has found power training, particularly at low load, significantly improves balance in a healthy elderly population (2006).

A popular form of power training is plyometrics; which utilize what is called the stretch-shortening cycle (SSC). The SSC involves a rapid eccentric muscle action, followed by a rapid concentric action of the same muscle-tendon unit (Komi, 1993). The SSC, a key feature of plyometrics, is believed to enhance muscle force and power production during the concentric phase of a given movement when compared to a muscle action only including a concentric action

(Komi, 1993). Plyometric training in an aquatic environment may provide the desired low load training for optimal power gains in an elder population. Currently, most research on aquatic plyometric training has focused on athletic performance in younger, not older, participants. Research on aquatic plyometrics in older adults may be particularly beneficial given that falls and decreased mobility are two of the major health risks associated with aging (Lui & Heise, 2013). A study of middle-aged participants may be a useful proxy for studying elderly populations.

Balance, like other aspects of fitness, can be improved by training. This view of postural control implies that balance control can be considered to be a fundamental motor skill learned by the central nervous system. Thus, like any other motor skill, postural control strategies can become more efficient and effective with training and practice (Pollock et al., 2000). The most common ways to train for balance are by doing balance specific exercises on land. The American College of Sports Medicine recommends a minimum of 2-3 days of balance training a week, but a person could do balance training every day with no contraindications. Most agree to improve balance a combination of strength and flexibility training is required. Exercises that focus on the postural muscles while decreasing stability have been found to be successful. There is much research that activities such as Tai Chi have been found to improve dynamic balance (Wolf et al., 1997; Tsang & Hui-Chan, 2003). There are also a variety of training aids such as balance disks, foam pads, balance boards, and stability balls to overload balance training.

While the majority of balance interventions are performed on land, there are few studies that have investigated an aquatic environment for training balance. Those that may need balance training the most are those that could also benefit from other exercises performed in an aquatic environment. Prior research suggests that performing jump movements in the water may also target improvement in balance (Louder, Searle, & Bressel, In Press). Kinetic characteristics of the take-off phase for jumping movements suggest that in comparison with land, jump landings in the water may be more unpredictable due to the resistive effect of fluid drag during upward propulsion of the body. Because of fluid drag, time in the air is not linearly related to take-off velocity for jumps performed in the water. Thais may result in a more unpredictable landing and provide a unique training environment for improving dynamic stability.

Additionally, our previous work on static balance suggests that the aquatic environment influences a person's ability to control the position of their center of pressure within a base of support. Specifically, we observed greater sway areas for young and older adults performing 90s static balance trials in the water compared to on land. Moreover, in comparison to the land environment, both older and younger participants self-reported on a visual analog scale that they felt "less stable" in the aquatic environment (Louder et al. 2014).

Ground reaction force (GRF) values, captured from a force platform, can be used to quantify and measure dynamic stability and the landing forces associated with the different phases of a plyometric jump.  (Ebben, Vanderzanden, Wurum, & Petushek, 2010b; Liu & Heise, 2013; Ross & Guskiewicz, 2003). Time to stabilization (TTS) is a quantifiable force plate measure used to evaluate dynamic stability. This variable measures the vertical component of stability from a force-time curve. Then a decay regression is taken to find the time to stabilization and is shown to be reliable and valid for this purpose. (Donoghue et al., 2011; Ebben et al., 2010b; Liu & Heise, 2013, Ross & Guskiewicz, 2003; Ross, Guskiewicz, Prentice, Schneider, & Yu, 2004; Ross, Guskiewicz, & Yu, 2005; Wikstrom, Powers, & Tillman, 2004).

There are very few studies that explore the relationship between dynamic stability in an aquatic environment. The studies that are available are limited since they did not include older adults. A study focusing on a comparison of dynamic stability across age, environment, and jump type is needed to provide evidence to strength and conditioning professionals and clinicians that could improve balance training prescriptions across age groups.

Therefore, the purpose of this study was to compare dynamic stability on land and in waist-deep water, between young and middle-aged adults performing plyometric exercises. Based on environmental conditions, we hypothesized that our measure for dynamic of stability would take longer time to stabilize in the water than on land. TTS results could potentially indicate which environment serves as a more effective stability-training aid in developing dynamic stability. Age-related hypotheses were based on the decreased muscular power of older adults, where we expected to see greatest TTS values and higher impact forces for middle-aged than younger participants.

**Methods**

Participants

Twenty adults between 18 and 50 years of age participated in this study. Participants were separated into a "young" or "middle-aged" group based on age young: 18-30 years, middle-aged: 40-50 years (see Table 1 the in appendix for participant details). Participants were recruited from Utah State University and surrounding areas. The age limit of 50 years was chosen to ensure the safety of participants since previous research has indicated that muscle power decreases drastically after this age (Macaluso & DeVito, 2004). The decrease in power may substantially increase the injury risk for these individuals, therefore, we collected data on moving on to the next environment. Greater trochanter water level was used as the landing height for all jumps because proper squat and countermovement jump techniques would completely submerge the subject underwater if a xiphoid water depth was used.

Land jumps were completed wearing shoes while aquatic jumps were completed barefoot. The reasoning behind the footwear protocol was that in a real-world environment, people are more prone to wear shoes on land and be barefoot in the water. Land and aquatic jumps were executed on the same waterproof force platform (AMTI, Model OR6-WP, Watertown, MA) that was placed on an adjustable-depth treadmill platform (HydroWorx 2000, Middletown, PA).

Data Collection and Analysis

Force platform hardware was calibrated before testing and reset for each environment condition, and the force platform was tared before each jump. Impact force data were collected via NetForce software (AMTI). The software was manually triggered to record 20 seconds of data (1000Hz), which was enough time for participants to complete a full jump. Data were filtered with initial landing occurring at an RFD of 10,000 Newtons per second between two successive data points. This is because initial contact is more difficult to identify underwater due to the gradual increase in vertical force before a more exponential increase. This method has been shown to be accurate to 0.02 seconds compared to video analysis (Donoghue et al., 2011).

Data were analyzed in Microsoft Excel (Microsoft Corp., Redmond, WA) before being calculated into the following absolute and normalized, if applicable, dependent measures for the landing phase: TTS, time to peak force, peak force, rate of force development (RFD), and impulse. TTS was calculated from the dampening of GRF fluctuations over time. We followed the procedures outlined by Liu and Heise (2013) in our analysis which calculated TTS as described in Figure 1 using Equation 1 that was modified to fit our data collection, which included more data points due to the increased frequency of collection. Data after the initial landing point was considered for TTS analysis, which continued for 10 seconds after the threshold was met (Liu & Heise, 2013). The sequential averaging was performed using Python (Python Software Foundation, Beaverton, OR) to expedite this process, and Excel was used to determine the point where the sequential average diminished to within one quarter of the overall standard deviation using logical functions (Liu & Heise, 2013). The landing impact measures chosen mimicked those done by Donoghe et al. (2011) that observed all the dependent measures as normalized to body weight, with the exception of TTS. In our study, these measures are reported absolute and normalized for each participant via body weight (Newtons), measured by the force platform when data were collected. Land and water body weights were used accordingly to the environment the jumping trial took place in. Table 3 in the appendix describes how each of these variables was calculated.

Statistical Analysis

Time to stabilization was the dependent measure and was analyzed using a 2 (age) x 6 (condition) Repeated Measures Analysis of Variance (ANOVA) with SPSS version 21 software (IBM, Chicago, IL). The repeated measures ANOVA were performed for each variable with age and condition as independent variables. This reported any significant main effects ($\alpha = 0.05$) between age groups or between jump types and their environment. Within-subject effects were also tested to observe if any age and dependent variable interactions were present. Cohen's d effect sizes were assessed to find the meaningfulness of any significant differences.

**Results**

TTS was significanty different between environments for the countermovement (CM) (p= 0.03, effect size [ES] = 0.79) and squat jump (SJ) (p = 0.04, ES = 0.72), but not for drop landing (DL) (p = 0.33) (Figure 1 . There was no difference in TTS between young and middle-aged participants (p = 0.99) (Figure 2), nor was there an interaction between the age groups (p = 0.51).

**Discussion**

The purpose of this study was to compare dynamic stability between younger and middle-aged adults performing plyometric jumps on land and in waist-deep water. Our study is the first we know of to measure dynamic stability on land and in the water for plyometric exercises. Our results for TTS on land (average ± standard deviation: 1.42 ± 0.34 s) are different from Ebben et al. (2010b) (0.65 ± 0.15) who included the same plyometric jumps. The discrepancy is likely explained by the participants we selected. Our study included participants with no activity level requirement and as expected, they displayed greater TTS values than those reported by Ebben et al. (2010b) who used athletes with annual training programs that involved plyometric exercises.

One interesting finding from our results is regardless of the plyometric jump used. TTS was significantly shorter in water than on land, but there was no difference between environments while doing the drop landing (Figure 1). These results are consistent with previous research on land (Franz et al. 2015) and indicate that properties of water may actually contribute to shorter stabilization times or improved dynamic stability.

We hypothesized that there would be a greater time to stabilization due to unfamiliar motor programs and that static stability is worse in water than on land. These results do not support our hypothesis and indicate that properties of water may actually contribute to shorter stabilization times. One possible reason we thought could explain this faster stabilization time could have been due to lower peak force values provided by buoyancy of the aquatic environment (Colado et al., 2010; Donoghue et al., 2011; Martel et al., 2005; Miller et al., 2007; Robinson et al., 2004). However, a post-analysis linear regression indicated no significant relationship between peak force and TTS (Figure 3). Another possible explanation is that lower TTS values in water due to enhanced focus and proprioceptive body awareness due to increased hydrostatic pressure and fluid viscosity (Roth, Miller, Richard, Ritenour, & Chapman, 2006).

We found lower TTS for both on land and in water in the drop landing compared to the countermovement or squat jump. The lack of a difference between environments in the drop landing may be attributed to the lack of a propulsive take-off, requiring less skill to do the exercise. This could be due to the decreased difficulty level of the drop jump allowing for more focus to be on the landing not performing the jump. Also there were verbal instructions to land and stabilize as quickly as possible for this jump where the other two didn't have that instruction. For future research, it would be wise to keep the verbal instructions the same with each of the jumps.

While there were significant differences in TTS between different environments there was no statistically significant difference between age groups nor any interaction showing different responses to environments by age. We hypothesized that the TTS would be greater for middle-aged participants indicating a decline in the ability to regain balance after a disturbance, however, the observed results between age groups contradict our hypothesis. This may be due characteristics of the middle-age group used in our study. The reason we chose a middle- age group to compare was to ensure safety in the jumps. However, our middle-age group may not have experienced a sufficient age-related decline in musculoskeletal and sensorimotor systems that affect dynamic stability. Future research may wish to consider an older population age 65 or older to determine an age difference in dynamic stability. Our research showed that it was safe to perform plyometric jumps with a middle-aged population thus suggesting that we could safely perform the test with an older population.

Implications of this research apply to athletic, rehabilitative, and training professionals. Since TTS was not different between age groups, with shorter stabilization times in water than on land, an aquatic training program could prove to be an effective preliminary step to improving dynamic stability before progressing on to more advanced stability training activities on land. An aquatic balance training program can help improve dynamic stability without putting the person at a higher risk of falling, this would be especially beneficial for clinical and elderly populations that are at a high fall risk. Water-based plyometric exercises have shown to be just as advantageous for increasing many physical attributes such as strength, power, and neural adaptations regardless of age or fitness level compared to land-based plyometrics (Markovic & Mikulic, 2010). Aquatic plyometrics may help improve and recondition components of muscular power that will improve mobility and decrease fall risk for middle-aged adults (Liu et al., 2006; Reid & Fielding, 2012).

Two of the main limitations of this study are the difference in footwear protocol, and that the TTS was only analyzed in the vertical direction. The jumps on land were performed with shoes and the jumps in water were performed barefoot. This was done to simulate a real life situation, however changing the footwear could have changed the biomechanics of landing and thus influencing dynamic stability. The landing phase while running with shoes is primarily a heel strike while barefoot it is a forefoot landing. If this pattern is true while jumping then it could improve the dynamic stabilization in water. To accurately compare the two in future research, it would be advisable to maintain the same footwear on land and in water. As is known, dynamic stability doesn't only occur in one plane, but rather it has three planes of motion one in each the vertical, anterior-posterior, and mediolateral directions. Only analyzing the vertical component fails to recognize the other two directions. It would be interesting to do more research to see the difference between each of the three directions in regard to dynamic stability. Also, it would be interesting to test the ability to regain balance after an unexpected stimulus has been introduced in any direction and compare this on land compared to water.

This research has revealed many opportunities for further research and ways to improve the current study. As mentioned previously in the article, it would be wise to keep the verbal instructions the same with each of the jumps. This would improve the ability to compare the results between the different jumps. It would be interesting to see if different verbal cues affect the time to stabilization. This could help analyze the cognitive function required for dynamic stabilization. In future research, it would be advisable to maintain the same footwear on land and in water. This would help improve the current research to eliminate extraneous factors that could influence dynamic stability. There are opportunities for new research to analyze the effect of shoe type with dynamic stability and forces on land and in water. This would help to discover what is most advantageous to wear when doing plyometric exercises in the water.

Future research may wish to consider an older population age 65 or older to determine an age difference in dynamic stability. This would make the current research more generalizable to reach the senior population. Based on our research we found no age-related decline in middle-aged populations, but possible future research could measure TTS across a span of ages beginning with a middle-aged group and increasing age groups by each decade. Our other research found that it is safer for an older population to perform plyometric jumps in an aquatic environment thus enabling this research without much risk to this population. This could possibly reveal when the age-related decline begins and to see the slope of decline in dynamic stability.

More research is needed to test more completely dynamic stability in all 3 planes of motion. Measuring this data would give insights as to which area the client or patient has deficits in their dynamic stability. This would also be more generalizable and applicable to real life since functional activities are completed in all three planes of motion. It could be measured after a plyometric jump or after an unexpected stimulus is presented from any direction. In the aquatic environment, this stimulus could be introduced by water jets or a change in the treadmill speed and direction. Comparing these results to land and water could highlight which environment is safest and best to train dynamic stability in all three directions.

An area for future research would be to test the effectiveness of an aquatic based training program in improving dynamic stability. With the measurement of time to stabilization, it will be possible to track someone's progress and improvement throughout a training regimen. This would also be beneficial to test dynamic stability in other activities other than just jumping activities. It would be advantageous to test more functional activities such as walking or as mentioned previously regaining balance after an unexpected stimulus. This would give support and evidence to the claims of this research that an aquatic environment can be a good preliminary step to improving dynamic stability.

Clinical application found from this study is that an aquatic environment can serve as a helpful preliminary step in dynamic stability training. Performing plyometric type activities in an aquatic environment may improve dynamic stability and power in an elderly population. Muscular power is a key factor in maintaining functional abilities, and decreasing fall risk in an elderly population. Our research found that it safe for a middle-aged population to perform plyometric type jumps which suggest that an older population may be able to safely perform plyometric jumps in the water. With the variable or time to stabilization, clinicians may be able to measure the improvement of dynamic stability in their patients. Improvement in muscular power can be seen in the improvement of dynamic stability. Thus improving dynamic stability and muscular power is an important factor to reduce the risk of falls in an elderly population.

**Conclusion**

Our findings showcase the differences in dynamic stabilization between different environments and age groups. The measure of dynamic stabilization (TTS) was lower in water than it was on land, with no difference between the younger and middle-aged groups. This may indicate that regardless of age, an aquatic environment may be a good first step in training dynamic stability. (4,128 words)

**References**

Arazi, H., & Asadi, A. (2011). The effect of aquatic and land plyometric training on strength, sprint, and balance in young basketball players. *Journal of Human Sport & Exercise, 6*(1), 101-111. doi: 10.4100/jhse.2011.61.12

Baechle, T. R., & Earle, R. W. (2008). *Essentials of strength training and conditioning* (3rd ed.). Champaign, IL: Human Kinetics.

Bressel, E., Wing, J., Miller, A., and Dolny, D. (2014). High-intensity interval training on an aquatic treadmill in adults with osteoarthritis: effect on pain, balance, function, and mobility. *Journal of Strength and Conditioning Research, 28,* 2088-2096.

Crenshaw, J. R., & Grabiner, M. D. (2014). The influence of age on the thresholds of compensatory stepping and dynamic stability maintenance. *Gait & Posture*, *40*(3), 363-368. doi:10.1016/j.gaitpost.2014.05.001

Colado, J. C., Garcia-Masso, X., González, L. M., Triplett, N. T., Mayo, C., & Merce, J. (2010). Two-leg squat jumps in water: an effective alternative to dry land jumps. *International Journal of Sports Medicine, 31*(2), 118-122. doi: 10.1055/s-0029-1242814

Donoghue, O. A., Shimojo, H., & Takagi, H. (2011). Impact forces of plyometric exercises performed on land and in water. *Sports Health: A Multidisciplinary Approach, 3*(3), 303-309. doi: 10.1177/1941738111403872

Ebben, W., Flanagan, E., Sansom, J., Petushek, E., & Jensen, R. (2010a). *Ground reaction forces of variations of plyometric exercises on hard surfaces, padded surfaces, and in water.* Paper presented at The 28th Conference of the International Society of Biomechanics in Sports: Coaching and Sports Activities, Marquette, Michigan, USA. doi: 10.1519/JSC.0b013e318182034b

Ebben, W. P., Vanderzanden, T., Wurum, B. J., & Petushek, E. J. (2010b). Evaluating plyometric exercises using time to stabilization. *Journal of Strength and Conditioning Research, 24*(2), 300-306. doi: 10.1519/JSC.0b013e318182034b

Fransz, D. P., Huurnink, A., de Boode, V. A., Kingma, I., & van Dieen, J. H. (2015). Time to stabilization in single leg drop jump landings: An examination of calculation methods and assessment of differences in sample rate, filter settings and trial length on outcome measures. Gait & Posture, 41(1), 63-69. doi: 10.1016/j.gaitpost.2014.08.018

Heyward VH & Gibson AL. Advanced Fitness Assessment & Exercise Prescription 7 th ed. Human Kinetics: Champaign, IL. 2014

Hollman, J. H., Kovash, F. M., Kubik, J. J., & Linbo, R. A. (2007). Age-related differences in spatiotemporal markers of gait stability during dual task walking. Gait & Posture, 26(1), 113-119. doi: 10.1016/j.gaitpost.2006.08.005

Irmischer, B. S., Harris, C., Pfeiffer, R. P., DeBeliso, M. A., Adams, K. J., & Shea, K. G. (2004). Effects of a knee ligament injury prevention exercise program on impact forces in women. *Journal of Strength and Conditioning Research 18*(4), 703-707.

Komi, P. V. (1993). *Strength and power in sport* (2$^{nd}$ ed.). Blackwell scientific publications.

Louder, T., Bressel, E., Baldwin, M., Dolny, D. G., Gordin, R., & Miller, A. (2014). Effect of aquatic immersion on static balance. International Journal of Aquatic Research and Education, 8(1), 53-65.

Liu, K., & Heise, G. D. (2013). The Effect of Jump-Landing Directions on Dynamic Stability. *Journal of applied biomechanics, 29*(5), 634-638.

Macaluso, A., & DeVito, G. (2004). Muscle strength, power and adaptations to resistance training in older people. *European Journal of Applied Physiology, 91*, 450-472. doi: 10.1007/s00421-003-0991-3

Markovic, G., & Mikulic, P. (2010). Neuro-musculoskeletal and performance adaptations to lower-extremity plyometric training. *Sports medicine, 40*(10), 859-895. doi: 10.2165/11318370-000000000-00000

Martel, G. F., Harmer, M. L., Logan, J. M., & Parker, C. B. (2005). Aquatic plyometric training increases vertical jump in female volleyball players. *Medicine and Science in Sports and Exercise, 37*(10), 1814-1819. doi: 10.1249/01.mss.0000184289.87574.60.

Miller, M. G., Cheatham, C. C., Porter, A. R., Ricard, M. D., Hennigar, D., & Berry, D. C. (2007). Chest-and waist-deep aquatic plyometric training and average force, power, and vertical-jump performance. *International Journal of Aquatic Research & Education, 1*(2), 145-155.

Orr, R., De Vos, N. J., Singh, N. A., Ross, D. A., Stavrinos, T. M., & Fiatarone-Singh, M. A. (2006). Power Training Improves Balance in Healthy Older Adults. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences, 61*(1), 78-85. doi:10.1093/gerona/61.1.78

Pollock, A., Durward, B., Rowe, P., & Paul, J. (2000). What is balance?. *Clinical Rehabilitation, 14(4)*, 402-406.

Reid, K. F., & Fielding, R. A. (2012). Skeletal muscle power: a critical determinant of physical functioning in older adults. *Exercise and Sport Sciences Reviews, 40*(1), 4-12. doi: 10.1097/JES.0b013e31823b5f13

Robinson, L. E., Devor, S. T., Merrick, M. A., & Buckworth, J. (2004). The effects of land vs. aquatic plyometrics on power, torque, velocity, and muscle soreness in women. *The Journal of Strength & Conditioning Research, 18*(1), 84-91.

Ross, S., & Guskiewicz, K. (2003). Time to stabilization: A method for analyzing dynamic postural stability. *International Journal of Athletic Therapy and Training, 8*(3), 37-39.

Ross, S., Guskiewicz, K., Prentice, W., Schneider, R., & Yu, B. (2004). Comparison of biomechanical factors between the kicking and stance limbs. *Journal of Sport Rehabilitation, 13*(2), 135-150.

Ross, S., Guskiewicz, K., & Yu, B. (2005). Single-leg jump-landing stabilization times in subjects with functionally unstable ankles. *Journal of Athletic Training, 40*(4), 298-304.

Roth, A. E., Miller, M. G., Richard, M., Ritenour, D., & Chapman, B. L. (2006). Comparisons of static and dynamic balance following training in aquatic and land environments. *Human Performance and Health Education Faculty Research,* Paper 5. http://scholarworks.wmich.edu/humanperformance_faculty/5.

Tsang, W. W., & Hui-Chan, C. W. (2003). Effect of 4 and 8 week intensive Tai Chi Training on Balance Control in the Elderly.*Medicine and Science in Sports & Exercise,* 648-657. doi:10.1249/01.MSS.0000121941.57669.BF

Wikstrom, E. A., Powers, M. E., & Tillman, M. D. (2004). Dynamic stabilization time after isokinetic and functional fatigue. *Journal of Athletic Training, 39*(3), 247-253.

Wolf, S. L., Barnhart, H. X., Ellison, G. L., & Coogler, C. E. (1997). The effect of Tai Chi Quan and Computerized Balance Training on Postural Stability in Older Subjects. *Physical Therapy Journal of APTA, 77*(4), 371-381.

Wolfson, L. (2001). Gait and Balance Dysfunction: A Model of the Interaction of Age and Disease. *The Neuroscientist, 7*(2), 178-183. doi:10.1177/107385840100700212

Viljanen, A., Kulmala, J., Rantakokko, M., Koskenvuo, M., Kaprio, J., & Rantanen, T. (2012). Fear of Falling and Coexisting Sensory Difficulties As Predictors of Mobility Decline in Older Women. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences, 67*(11), 1230-1237. doi:10.1093/gerona/gls134

## Appendix

Table 1. Participant details and demographics.

| | Male | Female | Age | Height | Land mass | Water Mass |
|---|---|---|---|---|---|---|
| Young | 5 | 5 | 24.4±2.63 years | 172.34±10.49 cm | 73.99±8.26 kg | 42.7±6.49 kg |
| Middle-aged | 5 | 5 | 46.8±3.05 years | 173.23±10.54 cm | 76.36±19.35 kg | 49.58±16.15 kg |

Table 2. List of plyometric exercises, their purpose, and correct technique. SSC; stretch-shortening cycle. [1]; Donoghue et al. (2011).

| Plyometric Jumps | Purpose | Technique |
|---|---|---|
| Countermovement Jump | A fluid, unrestricted jumping motion that utilizes the SSC | Start in upright position, squat down, and jump as quickly as possible with hands on hips |
| Squat Jump | A restricted jumping motion that does not utilize the SSC | Start by holding an approximate knee angle of 90° before jumping with hands on hips |
| Landing Exercise | | |
| Drop Landing | A landing movement that does not have a take-off phase | Start on a platform 30cm higher[1] than the force plate, step off, and land on the force plate with hands on hips |

Table 3. List of dependent variables with simple definitions and positive value trends. *Reported via raw value or normalized to body weight measured in the environment the trial took place in. [1]: Liu & Heise (2013). [2]; Markovic & Mikulic (2010).

| Dependent Variables of Dynamic Stability | Calculation | Positive Value Trend |
|---|---|---|
| Time to Stabilization (TTS) | Time for sequential average (*Equation 1*) to diminish within ¼ of the overall standard deviation [1] | Lower values equal quicker stabilization |

Equation 1. Sequential averaging equation (Liu & Heise, 2013) Values reported as; average (standard deviation).

$$SeqAvgx(n) = \frac{\sum_{n=1}^{10001} Fz}{n}$$

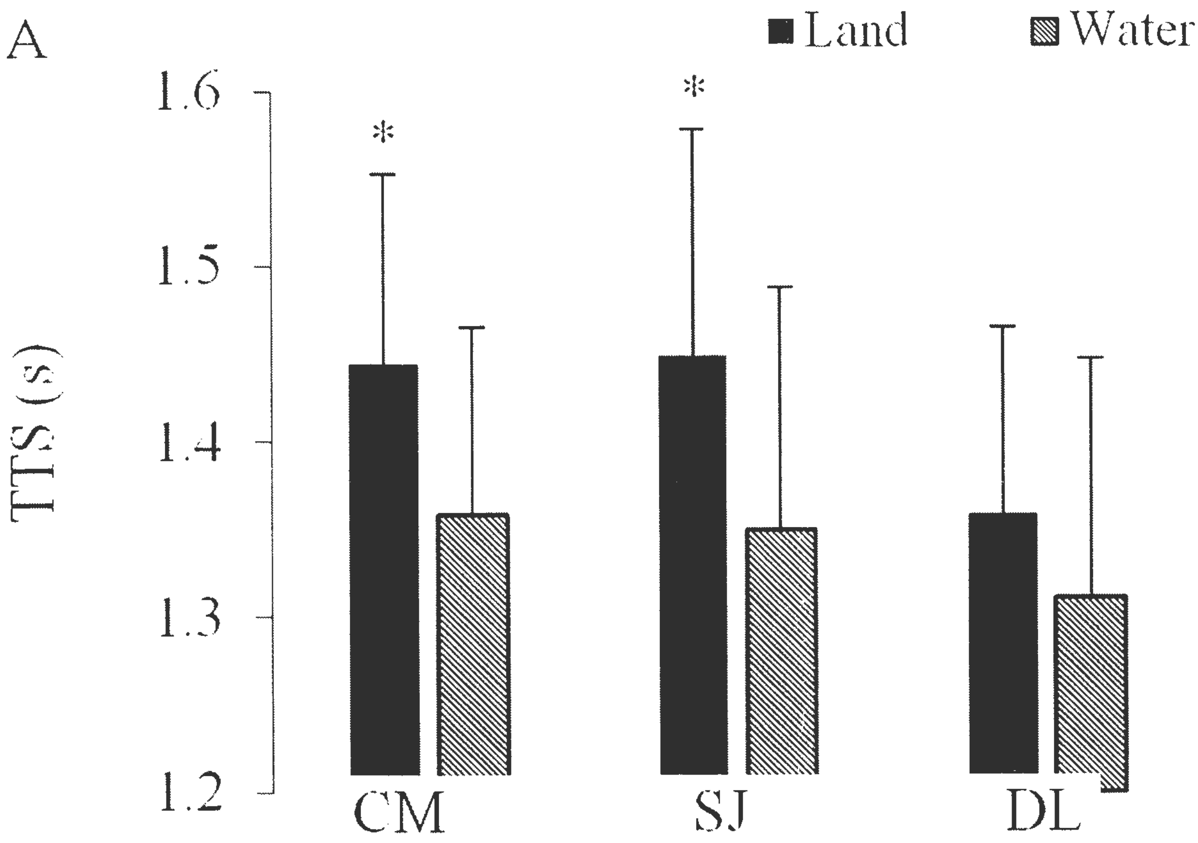


Figure 1. TTS was significantly different between environments for the countermovement (CM) ($p= 0.03$, effect size [ES] = 0.79) and squat jump (SJ) ($p = 0.04$, ES = 0.72), but not for drop landing (DL) ($p = 0.33$)

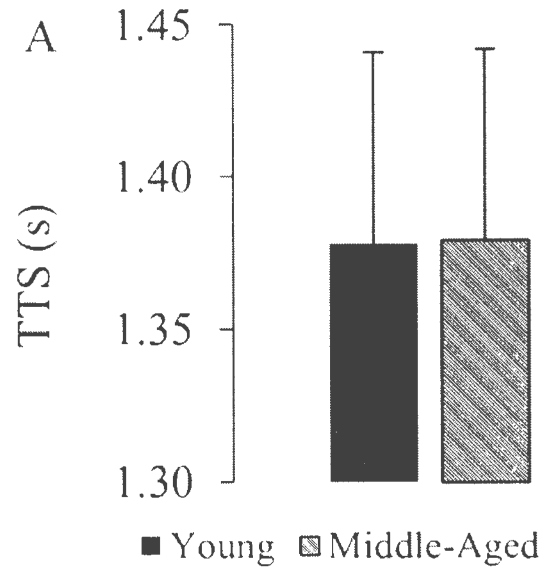


Figure 2. There was no difference in TTS between young and middle-aged participants (p = 0.99) (Figure 2), nor was there an interaction between the age groups (p = 0.51)

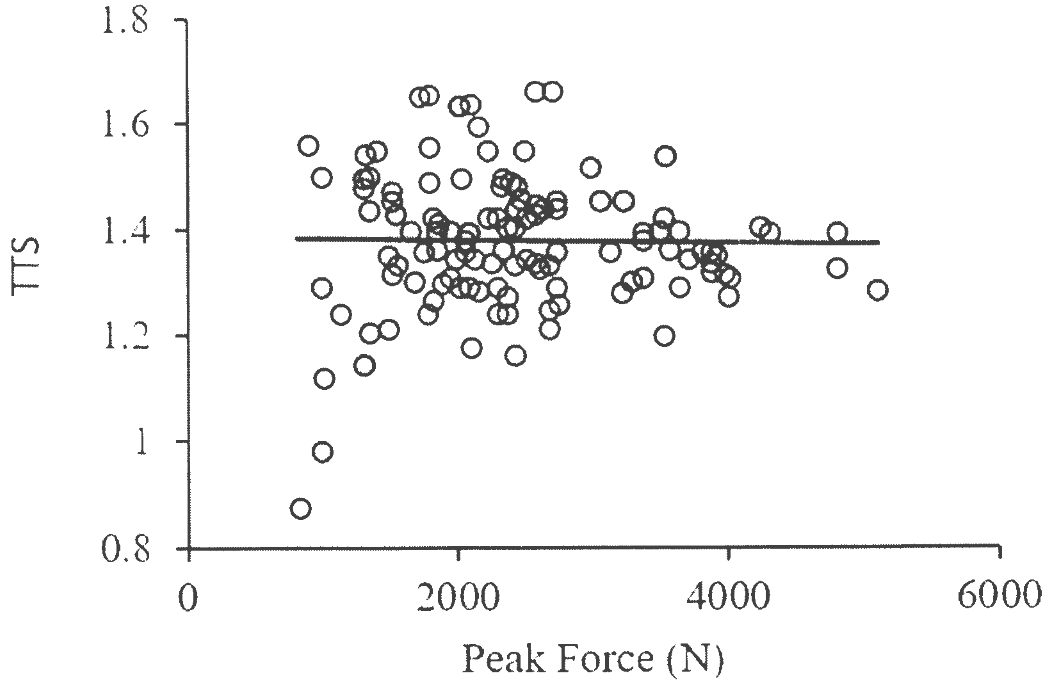


Figure 3. Linear regression showing the lack of a significant relationship between raw peak force (predictor variable) and TTS (response variable) ($F = 0.02, p = 0.89, R^2 < 0.01$).

**Personal Reflection Essay**

It was my first day back in classes after I took a church service leave for a year and a half, and my professor of Anatomical Kinesiology, Talin Louder, told us what he is doing for his research. He spoke of aquatic plyometrics, and aquatic therapy research. I, being a swimmer, was completely awestruck that he was researching exactly what I wanted to do. Just earlier that day I had spoken with Amber in the honors office discussing what I needed to do for a contract, and to start looking into ideas for my honors thesis. I had told her that I didn't know exactly, but something with aquatic therapy would be really cool. I had done some volunteer work with aquatic therapy and fell in love with that modality. I knew that in my future practice I would want to have aquatic therapy as part of a treatment plan. As soon as class was over, I ran up to talk to Talin to ask how I could get involved. He said that I could help recruit participants and to help with the data collection that was happening that Saturday. I left there feeling completely ecstatic at this opportunity.

That week I met with Talin and Cade, who were leading the research, to learn more about the project. I learned the method we were using, how they decided on the variable of time to stabilization, what they were looking for with decreased impact forces and dynamic stabilization, and what this could mean clinically with the results they were getting. The first main struggle they had was finding enough middle-aged participants. I went home that day and emailed everyone I knew in that age group. I was able to recruit five participants in this middle age category.

I wasn't able to be there at all of the data collection sessions, due to scheduling conflicts, but I was able to participate with the five participants that I recruited. I was able to help give the verbal instructions to the participants and demonstrate the jump types. Talin showed me the data collection from the force plate and explained to me what it meant. I learned about peak force, ground reaction forces, time to stabilization, and how to see them in the data what we collected. Each of the participants was very kind and willing to sacrifice their time to help us participate in the research.

That semester I used the data that we had collected for my final project in my Performance Evaluation in Physical Activity class. During this process, I learned how to do the statistical analysis tests ANOVA, T-Tests, and Post-Hoc Linear Regression. This proved to be challenging because there were repeated measures and multiple variables. I had to spend much time outside of class with my professor as we figured out how to run the data. Once we had our numbers and found our statistical significances, I learned how to use the statistical program R to run the data, and produce visually pleasing graphs. I also learned how to make a visually appealing poster presentation and had the opportunity to have a mini class poster session where I was able to present my findings orally.

After the semester, I thought that I was done with this project because I was going to do my thesis project about children with musculoskeletal disabilities and aquatic therapy. It proved to be challenging to get my thesis proposal in while I was at a study abroad in Peru for the fall semester, but after half a semester I solidified my proposal and had accumulated many resources of articles about children with musculoskeletal disorders and aquatic therapy. I found this topic very interesting, and my plan was to do a meta-analysis of the research that I had found. My adviser was on board, but we ran into an obstacle when I got home from my study abroad.

I met with Amber, and the requirements for a written paper that I was wanting to do was twice as long as I had expected, and at this point, I only had one semester left to finish it. We decided that it wasn't wise for me to continue on that path. I went to my capstone project adviser and asked what other options I had. Then we remembered that I had participated in this research last spring and that I could take a new angle focusing on the variable (TTS) and dynamic stabilization. Since this was a research based project, I had already spent many hours studying this, and I was collaborating with Talin and Cade, this looked like something that could be doable.

We quickly switched gears, I turned in a second thesis proposal that was approved by Dr. Miller and I was able to get started on my project. I started in mid-January, which was later than expected, but Dr. Bressel, my adviser, has been a huge support in giving suggestions, direction, and revisions to my project. He has helped immensely and taught me how to write a formal article. Writing the final project took more time than expected, but it was worth it. I feel like it is a huge opportunity and I wouldn't trade it for the world.

I would suggest to future honors students to start earlier on their thesis project, and choose something that is going to be doable within the time you have. I also suggest to future students to continue to be involved in the honors program both academically and socially throughout their time at USU. My time in Logan at Utah State has been an incredible journey filled with unexpected opportunities. Future students take advantage of every opportunity that comes your way because that will be what sets you apart from other students and what will make your experience at Utah State incredible. (984 words)

## Author Biography

Christie Bunnell was raised in Lindon, Utah and graduated from Pleasant Grove High School June 2011. Christie received many scholarships to Utah State University including an Aggie Alumni Scholarship, 4-H State Ambassador Scholarship, Utah County 4-H Scholarship, Amazon Student Scholarship, Utah Regents Scholarship, and an Academic Merit Scholarship. Service is a very important part of Christie's life. She completed two terms of AmeriCorps Service in 4-H and mentoring programs on campus. In the summer of 2012, she went to Thailand with Help International working with the Burmese Refugees in HIV/Aids prevention. She served a year and a half full-time mission in San Jose, California serving in the communities at food banks, homeless shelters, and community centers. In her college career, she has spent over 3,200 hours serving the local community.

Christie has served as an officer in the Collegiate 4-H Club, a Mentor in the Honors Program, Captain and Vice President of the USU Club Swim Team. Fall of 2015 she was selected to be a SEED (small enterprise education development) intern for the Huntsman School of Business, and helped people start their own businesses in Peru. She will graduate May 2016 with a degree in Human Movement Science with an Emphasis in Pre-Physical Therapy and a minor in Management. After graduation in May, she will continue her education in pursuit of a Doctor of Physical Therapy degree at the University of Utah.