A Comparison of Plyometric Training on Power Benefits, Body Composition, and Enjoyment

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Abstract

Introduction. Plyometrics has shown significant improvements for explosive power, strength, and body composition. **Purpose.** The purpose of this research study was to examine the effects on power in a land plyometric exercise program. It is important to note the issues for different effects on power when performing plyometrics in a periodized program in comparison to not participating in one. **Methods.** The study had 13 participants (10 males: 23.4±4.01 years, 3 females: 21.33±2.52 years), which were randomly selected to land plyometric training (LPT; *n*=6; 5 males, 1 female) or a CG (*n*=7; 5 males, 2 females). The study consisted of a pre-test, 8-week intervention, and a post-test the 10th week. Participant's vertical jump height (VJH), hang time, body composition, and physical activity enjoyment scores were recorded. A repeated measures ANOVA was utilized to determine between and within groups differences and Cohen's *d* was used to calculate effect sizes. The current study researched quantitative data to find statistical evidence for VJH. This study outperformed previous research in VJH with similar age groups, while younger participants in previous research outperformed the LPT group. **Results.** A significant effect over time was found for all groups in VJH (p= .045). LPT increased their VJH by a mean of 1.2 in (7.06%) and CG by 0.4 in (1.88%). Hang time also increased significantly over time among both groups (p= .032). LPT slightly decreased body fat percentage with a small negative d = .04, but this data was not significant (p= .080). **Conclusion.** The current study provides significant evidence for LPT being an effective method for increasing VJH over time but found no significance for time and group interactions. It should be noted the researcher could not control exercise participation outside of the research study, which could have confounded results. The fitness levels and age can also have an impact on increasing VJH. Future research should seek different training environments, increased sample size, and length of study.

CHAPTER 1: INTRODUCTION

Background and Significance

In the world of fitness, plyometric training is used as a tool to improve power movements for individuals who practice the skill in a fitness program, however this type of training is mainly used for improving athletic performance in athletes. According to Stemm and Jacobson (2007), plyometric training began to gain popularity in the early 1970's when Eastern European athletes started to dominate in power specific sports. Plyometric training has several different types of environments in which an individual can be trained, such as: water, sand, padded mats, grass, and hardwood floors. Studies showing an increase in VJH (vertical jump height) found that aquatic and land plyometric training programs cause similar increases in VJH (Bavli, 2012), while in some cases both programs outperformed one or the other and resulted in significant increases for vertical jump, horizontal power, and explosive power (Fabricius, 2011; Kamalakkannan et al., 2010). Structuring of programs varies for each study depending on the environment, repetition scheme, total number of days per week, intensity, how long the studies last, and whether any exercise equipment was used, such as dumbbells or resistance bands. The variations of these programs might be the cause of inconsistent results on the topic of plyometric exercise, because in some cases, the data varied. The studies conducted longer than six weeks seemed to have better increases for VJH, in comparison to studies six weeks or less. One factor of plyometric exercise in previous research has shown increases in muscle damage for the acute effects of bouts of plyometric exercise by Arazi et al. (2016b). Arazi et al. (2016a) states that the change in muscle soreness is due to the surface, and there is less muscle damage for sand and water than for firm surface environments. Water causes a resistive factor to the body's force when contracting and less impact when the foot contact occurs in the lengthening process of the muscle. The denser an object is, the more it will affect the object coming in contact with its own density. Water is approximately 800 times denser than the air we breathe (DiPrampero, 1986; Kamalakkannan et al., 2010). Arazi et al. (2016a) also mentions how the aquatic setting provides a therapeutic modality in result of the decreased stress on the lower extremities. Because land-based plyometric training is highly intense by nature, the impact would lead to overuses injuries (Ploeg et al., 2010). If aquatic plyometric training can prove to be just as beneficial, if not, more beneficial for increasing power than traditional land plyometric training (LPT), this type of training style could change the way strength coaches and fitness experts periodize their strength and conditioning programs.

Hypothesis and Purpose

The purpose of this study was to compare the effects on power between aquatic and land plyometric training programs, however, due to the COVID-19 pandemic postponements, the researcher's knee injury, and also pool heater issues at the training site, the study was changed to a comparison of a LPT group and a control group (CG) who were originally the aquatic group. The CG did not participate in plyometric exercise. Therefore, the purpose of this study was to compare the effects of plyometric training on VJH, hang time, and body composition between an LPT and CG during an eight-week plyometric intervention. The research question is: Is a control or land plyometric program more effective for increasing VJH? A secondary question is: Is a land plyometric program effective enjoyable and effective at improving body composition? The null hypothesis states that the CG will result in no difference in VJH in comparison to the land group. The researcher hypothesizes that LPT will be a more effective method for increasing VJH.

Limitations

The researcher was aware the participants could possibly not adhere to the instruction provided by the researcher. Participants were to continue with their regular workout regimen during the intervention and not to perform plyometric exercise outside of the intervention. The researcher knew this may affect the study design and lead to errors in the statistical evidence. The neglecting of these duties and neglecting to inform the researcher could lead to a self-reporting error as well. Possible limitations were known if the participants did not adhere to the instructions, in which the individuals may not be properly performing the exercise with good technique, which could lead to injury and lower increases for power. The researcher reminded participants during every session about technique, performing the movement efficiently, and explained the activation areas to focus on when performing the jumping movements. The testing was in a natural environment, with no control of external factors, as intended in this study. The subjects were limited to Mercy Fitness Center Edmond I-35, as the gym was the target location for the natural setting.

Delimitations

The delimitations of this study were as follows: participants needed to have been participating in resistance exercise at least twice a week for the past 12 months, must have been free from any exercise limitations, and also be free from any major lower body injuries in the past three years. The researcher knew to the best of his knowledge the participants had been participating in resistance training twice a week for the past 12 months with the significant impacts of the COVID-19 pandemic and gyms closing. Another delimitation was the study was using a small sample population at Mercy Fitness Center Edmond I-35 and the University of Central Oklahoma email blast, which is limited to the members at their facility and anyone at the university who received and responded to an email. The study was also limited to participant ages 18-40 due to the high intensity of plyometric training.

Assumptions

The researcher assumed that the participants would abide to all duties that did come with participation and would also attend all 18 sessions. The researcher assumed participants would not exercise before pre-testing and post-testing to ensure accuracy of the skinfold caliper for body fat percentage measurements and the VJH test. The researcher also assumed the participants would maintain their current exercise regimens, participants would not in exercise before training sessions, and participants would not perform any plyometric activities outside of the study during the eight-week intervention. It is assumed that the use of tools would be accurate and correct exercise techniques would be performed when measuring the pre-intervention and post-intervention numbers to ensure the accuracy of the statistical analysis.

Operational Definitions

- VJH- highest point an athlete can touch from a standing jump, less the height that the athlete can touch from a standing position. (“Vertical Jump,” 2007)
- Power- The product of force and velocity; the ability to exert force quickly. (Plowman & Smith, 2017)
- Power Movements- a combination of strength, speed, and force times velocity (Radcliffe & Farentinos, 2015). A quick, powerful movement using a pre-stretch, countermovement, that involves the stretch-short cycle. (Haff & Triplett, 2016)
- Plyometric Exercise- a type of training that involves jumping with maximal force in the shortest amount of time to help increase power movements involving the stretch-shortening cycle. (Haff & Triplett, 2016)

- Resistance Training- defined as a specialized method of conditioning whereby an individual is working against a wide range of resistive loads to enhance health, fitness, and performance. (Haff & Triplett, 2016)
- Lower Body Injury- any type of damage to a person that constitutes pain or suffering to any part of the body from the waist down, such as: the hip, groin, leg, knee, ankle, and foot injuries.
- Exercise Volume- relates to the total amount of weight lifted in a training session. (Haff & Triplett, 2016)
- Stretch-Shortening Cycle- employs the energy storage capabilities of the SEC (series elastic component- muscles and tendons. (Workhorse of plyometric exercise) and stimulation of the stretch reflex to facilitate a maximal increase in muscle recruitment over a minimal amount of time. (Haff & Triplett, 2016)

CHAPTER 2: LITERATURE REVIEW

Introduction

Plyometric exercise has been shown to be beneficial for improving athletic performance in individuals. The benefits include increased power movements, strength, agility, speed, and coordination. Do the same benefits occur, especially in power movements, when plyometric exercises are performed in an aquatic environment? The concept of aquatic plyometric training is not new (Fabricius, 2011), but there is not a lot of information on the acute effects of plyometric exercises on different types of surfaces (Ebben et al., 2010). It is important to recognize the benefits of aquatic plyometric training because of reduced muscle soreness from the low impact effects buoyancy (Arazi et al., 2016a; Fonesca et al., 2017; Shaffer & Sandrey, 2007; Tofas et al., 2008), which could lead to better alternatives for athletes to utilize during heavy training programs or in-season training to prevent the possibility of an overtraining stimulus. Aquatic plyometric training has been beneficial in reducing muscle soreness (Wertheimer et al., 2018) and has shown to significantly increase VJH (Fabricius, 2011; Bavli, 2012; Fonesca et al., 2017; Kamalakkannan et al., 2010). The reduction in delayed onset muscle soreness (DOMS) could lead to increase frequency of plyometric training methods, which in turn could lead to greater increases over a training period**.** The deeper the water, the more an individual's body weight is reduced, and Kamalakkannan et al. (2010) quoted three separate articles stating the downward pull of gravity while being submerged in water can reduce body weight up to 90% (DiPrampero, 1986; Darby & Yaekle, 2000; Wilder & Brennan, 2004). This literature review used other effects on power in different plyometric environments such as increase of power for countermovement jumps, single leg bouts, squat jumps, speed changes, agility, etc. As stated earlier, the effects of plyometric training can improve more than just vertical jump and also increase the overall performance of athletes. The purpose of this literature review was to compare the effects on power between aquatic and land plyometric programs. The organization of the literature review includes how the articles searched for were conducted and the methods to find the articles. The review includes the results and used three subtopics: effects on power movements and muscular strength, muscle soreness, and impact forces. Further analysis of the results are discussed in the discussion section to summarize the findings of the literature review.

Methods

The findings for the literature were found through the University of Central Oklahoma Chambers Library database and Google Scholar, using the Directory of Open Access Journals, EBSCOhost SPORT Discus, PubMed Central, Journals Ovid, ProQuest Central, SAGE Premier, EBSCOhost Acedemic Search Premier, Elsevier Science Direct Journals, Tyler & Francis Journals Complete, and Oxford University Press Journal Current databases. The following are the key words used in finding literature for the review: *aquatic versus land plyometric, aquatic plyometric, effects of plyometric training, aquatic plyometric increases vertical jump, aquatic plyometric power, aquatic plyometric muscle adaptation, aquatic plyometric muscle soreness, aquatic plyometric impact, aquatic plyometric neuromuscular adaptation, aquatic plyometric volume frequency and intensity, aquatic plyometric recovery*. The author reviewed 43 articles comparing the different effects in aquatic and land plyometric programs. No ages were excluded for this literature review, although the age populations ranged from 14-30 in the majority of the studies, except for one study, in which physically active postmenopausal women aged 59-67 were measured for body composition change and explosive strength (jump height) during a plyometric intervention. The paper was designed to review the benefits of aquatic exercise and changes in vertical jump of land and water-based training, so all ages and fitness levels were included into the review. The inclusion criteria also consisted of factors that are benefits of plyometric exercise for vertical jump increases, such as increase in agility, sprint speed, reduced muscle soreness, strength, balance, and body composition. The quality of the review assessed the bias of the literature and found that most studies tested college-aged individuals, especially male participants. The majority of studies used male participants (Male, n= 580, Females, n=160). The criterion for gender was not mentioned for four interventions totaling in 97 participants. Even though none of the study designs were excluded, the literature was included in the review because of vertical jump inclusion criterion. Criteria was reviewed to ensure that appropriate quality standards were met to provide direction to the aim of review, which was to assess and compare statistical differences in land and aquatic plyometric exercise for VJH and all other inclusion criteria. The literature review included data from the increases in power for all plyometric movements, muscle soreness, and athletic performance change for factors that are complimented by plyometric training, such as speed, coordination, and agility. Most of the data was taken from a college-aged population and summarized to compare the effects. The comparison in middle aged and older populations would be beneficial, but little research has been conducted in the subject of aquatic plyometric training for those populations.

Results

Effects on power movements and muscular strength

Fabricius (2011) compared the aquatic and land-based plyometric program in 52 rugby players between the ages of 15 and 19 years old. Land, aquatic, and control groups were set and put through a protocol to inform participants about proper technique. Participants were assessed before and after the intervention, measuring peak power and peak velocity using Fitrodyne repeated countermovement jumps, Seargeant vertical jump, standing broad jump, agility, and speed. Participants trained by doing jumps in place, standing jumps, multiple hops and jumps, bounds, box drills, and depth jumps. The intervention entailed 14 sessions over a seven-week period. The land group was the only group to have significant increases in peak power ($p < 0.05$) and increased it by 5.59% (ES: 0.26), but no significant differences were found between the groups. The effect of the seven-week intervention showed no improvement in power for maximum peak (0.33%) and average (0.75%). Land showed higher values than aquatic-based in minimum (ES: 0.52) and maximum (ES: 0.22). In the Seargeant vertical jump, aquatic group showed the greatest performance increase from pre to post testing by increasing 1.56 in (land 1.38 in). The aquatic plyometric group increased horizontal power by 3.6% and 5% by control, and no improvement on land. No improvements for speed were found and the aquatic group was the only one to show practical significance for pre to post-test values (3.01%; ES: 0.51).

Ebben et al. (2010) tested the variations of hard surface, padded surface, and in water for plyometric exercise. Participants were performing a single test for each measurement in each variable. Fifteen men and women age 21.2 ± 2.2 years performed drop jumps from 46 cm, single leg jumps using the right leg, counter movement jump, squat jump testing for takeoff peak, time to takeoff, power, jump height, and landing peak. Significant differences were found between land, mat, and water. The water group had a jump height in meters of 0.66 ± 0.13 m (66 cm), while land group and mat group was at 0.31 ± 0.08 m (31 cm). A significant difference for power was found between land versus water, and mat versus water ($p < 0.001$), but jump height and power values were calculated based on a certain flight time equation, so the statistics may be false due to buoyancy. The statistic is interesting to note because participants ended up jumping significantly higher in the water in comparison to the other environments.

Bavli (2012) compared the effects of water and land plyometric training over a 12-week intervention in 91 adolescent basketball players (male = 48, female = 43) ages 16 ± 1 year. A land (*n* = 30), water (n = 31), and control group (*n* =30) were used. Test were conducted for BMI, one repetition maximum leg strength, 30 m sprint, vertical jump, and flexibility. The aquatic group from pretest to post test showed about the same increases in vertical jump as land. Land pre 48 ± 9.3 cm and post 52.6 ± 8.8 cm, aquatic pre 47.2 ± 5.2 cm and post 51.7 ± 5.2 cm. One repetition on max leg strength showed about the same increases in kg as well for land and aquatic training. Land pre 135.5 ± 1 kg and post 197.5 ± 51.3 kg, aquatic pre 135.7 ± 44.9 kg and post 200.7 ± 45.7 kg.

Arazi & Asadi (2011a) tested the effects of aquatic and land plyometric training over an eight-week intervention in 18 young male basketball players ages 18.81 ± 1.46 years. The study was divided into three groups: land, aquatic, and control group. Experimental groups were tested for leg press strength, 36.6 m & 60 m sprint times, long jump, vertical jump, and T test. No results were provided, but the researchers stated there were significant improvements in agility, sprint, and power.

Arazi & Asadi (2011b) tested differences in the same group of basketball players over an eight-week intervention for strength, sprint speed, and dynamic balance. Subjects performed ankle jumps, speed marching, squat jumps, and skipping drills for 40 minutes, three times a week. Although both aquatic and land showed increases in leg strength, there was no significant difference between the land and aquatic group. The aquatic group showed significantly larger increases than the control group.

Arazi et al. (2016a) did a study comparing the effects of several different types of grounds surfaces in plyometric exercise. The plyometric exercises were tested on 24 college-aged men that were split up into three separate groups: aquatic, sand, and firm group. The participants were tested on bouts of plyometric exercises using a scheme of 10 sets of 10 reps, and were reevaluated after a 24 hour (hr), 48 hr, and 72 hr period. The researchers measured creatine kinase levels, delayed-onset muscle soreness (DOMS), range of motion (ROM), isometric strength, VJH, and sprint speed for each time period mentioned. The results showed that the values measured were significantly higher in some measurements in the firm group at the 24 hr period than the sand and aquatic groups, and the values remained higher than baseline at 72 hr for firm surfaces. VJH was measured to show the effects each surface type had on the body after the bouts of exercise. All groups decreased in height, but the firm surface group had the greatest decrease, while the sand and aquatic environment had similar decreases.

Ceran, et al. (2011) did a supplemental study on comparing the effects of aquatic and land-based plyometric training in 13 college students ages 21.77 ± 1.42 years over a four-week period, training three times a week. Both the land and aquatic group showed significant increases in post-training vertical height ($p < 0.05$). VJH increased for land group 4.02 ± 2.19 cm and aquatic group 4.72 ± 1.59 cm, but no significant differences were found between the groups. No statistical results were provided, but the research suggests aquatic training can have the same benefits as land based.

Colado et al. (2009) did an eight-week program testing the short-term effects of aquatic resistance in twenty men ages 21.2 ± 1.7 years. A control group (n= 5) was established for a comparison to the aquatic training group (n= 7). Only twelve of the participants completed the study. Participants trained three times a week, with the control group their normal routines and the aquatic group used devices that created drag force and a cadence to match the intensity needed for testing. Bench press, lateral raises, horizontal bench row, vertical row, and squat jump were measured to test the differences after the program was completed. There were no significant changes in the control group for all variables. The aquatic group improved strength in every category, including a significant increase in upper-limb strength and leg muscular power. Squat jump at pre-test had a Means $\pm$ SD of 4471.07 $\pm$ 581.37 watts and a post-test increase of 135.62 $\pm$ 141.84 watts, which is a 3.03% increase, while the control group decreased strength in participants. This article is relevant because the significant changes found for power in aquatic plyometric exercise shows an aquatic environment can be as beneficial for improving VJH as LPT.

De Villarreal et al. (2009) compared enhancing performance in 30 professional water polo players ages 23.4 $\pm$ 4.1 years for a six-week period, three times a week. The three groups were: combined training, plyometric, and water-specific strength. The 10 m T-agility test, 20 m maximal sprint swim, maximal dynamic strength for bench press and squat, in-water boost, countermovement jump, and throwing speed were measured before and after training. The water-specific group showed significant differences in water jump, one repetition max of full squat, and throwing speed, which are signs of increase in power. The water-specific group at pre-test for VJH was 39.1 $\pm$ 3.1 cm and post-test values increase significantly to 40.2 $\pm$ 4.2 cm, while the land group increased their VJH from 39.3 cm at pre-test and 41.7 cm at post-test.

Fonesca et al (2017) performed a study measuring DOMS as an analogue scale and VJH on a leap jump platform. The study was six weeks testing 24 male Brazilian soccer players ages 16-18. The participants were split into three groups of eight: aquatic, land, and control. The control group was told to perform no jumping activities during the intervention. Both the land and aquatic groups had significant increases in their VJH. Aquatic plyometric training (APT) was 36.57 cm at pre-test and 45.93 cm at post-test, while the land plyometric training (LPT) was

40.16 cm at pre-test and 46.29 cm at post-test, with the APT having an effect that indicated a strong improvement for VJH (APT, $d= 5.37 > 0.82$; LPT, $d= 3.48 > 0.82$).

Kamalakkannan et al. (2011) tested the effects of aquatic plyometric training with and without weights among 36 volleyball players ages 18-20. Three groups were made and categorized as a control group, plyometric training with weight, and plyometric training without weight, with 12 participants in each group. The control group received no training, but the other two groups trained three times per week for 12 weeks. The participant's speed, endurance, and explosive power were measured at pre and post. The aquatic group with weights has the highest increase for explosive power from pre-test (45.30 ± 5.84 cm) to post-test (51 ± 5.75 cm) on vertical jump. The aquatic group without weights measured 45.75 ± 5.67 cm at pre-test and 48.90 ± 5.76 cm on VJH. The unit of measurement is not mentioned in this study, but the researcher assumes the units are measured in centimeters.

Lavanant et al. (2013) compared the effects of aquatic (EPA) and land plyometric training (EHE) in 24 physical education students ages 21 ± 2.7 years. Participants trained two times per week for six weeks, testing four times (squat jump and countermovement jump for pre & post). There were no significant differences found between the two groups, but both groups showed to improve jump capacity. EPA and EHE were shown to have a better capacity in squat jump between the first and last jump of 0.38 ± 0.77 m (38 cm) versus 0.37 ± 0.03 m (37 cm).

Lavanant et al. (2017) compared the effects of land versus aquatic plyometric exercise on 65 male physical education students. The program was conducted for 10 weeks, with sessions twice a week, increases jumps every week from 10 sets of 10 the first week to 10 sets of 55 the tenth week. The participants were split into three groups: aquatic (APT, $n= 20$), land (PT, $n= 20$), and a control group (CG, $n= 25$). A Bosco Ergo-jump plus system measured jump capacities.

The jump test used was a squat jump and a countermovement jump, with strict protocols on how jumps were valid or invalid for the two attempts. Before (T1), intermediate (T2), and after (T3) measurements were taken during the intervention. Both experimental groups showed to increase their countermovement jump and squat jump, but no significant increase was found between the two groups. Squat jump improved from T1-T3 in aquatic group (T1, 31.5 $\pm$ 3.6 cm; T3, 35.1 $\pm$ 6.0 cm) and also improved for land group (T1, 29.8 $\pm$ 5.8 cm; T3, 34.1 $\pm$ 5.4 cm). Countermovement jump improved from T1-T3 in aquatic group (T1, 33.5 $\pm$ 4.3 cm; T3, 36.9 $\pm$ 9.0 cm) and also improved for land group (T1, 31.4 $\pm$ 4.9 cm; T3, 35.0 $\pm$ 5.0 cm).

Ploeg et al. (2010) compared the effects of high volume aquatic plyometric training for vertical jump, muscle power, and torque in 39 adults (males= 16 ages, 21.8 $\pm$ 2.3 years; females= 23 ages 22.4 $\pm$ 3.5 years) and were randomly assigned to four groups: aquatic group one, aquatic group two, land group, and control group. The test was done over a six-week period and all participants performed plyometric exercises. The aquatic group one and land group performed the same amount of volume, while aquatic group two doubled the volume. The aquatic group two was the only group to have a significant increase in the performance variables. The control group had the greatest increase in vertical jump of 2.6 cm. The aquatic group one only increased vertical by 0.3 cm, aquatic group two increased by 1.3 cm, and the land decreased by 1.3 cm. This study is valuable because the research has statistical data for doubling of the volume of exercise to cause a decrease in VJH.

Ramirez et al. (2015) tested explosive strength and body composition in 36 healthy postmenopausal women ages 63.2 $\pm$ 3.99 years. Participants were split into two groups: land group (*n*= 19) and swimming pool group (*n*= 17). The groups trained three times a week for 22 weeks using multi-jump exercises. Both groups had significant changes for increasing explosive power, reducing body fat percentage loss, and increasing muscle strength.

Veliz et al. (2014) looked at the effects during an 18-week program during season of elite water polo players on heavy-resistance, power training for throwing velocity, strength, jumping, and maximal sprint swim. The study consisted of 27 male participants ages 20.43 $\pm$ 5.09 years and were split into two groups: control (in-water only) and strength group (strength training sessions + in-water training). Measurements were taken at pre-test and post-test for 20 m maximal sprint swim, maximal dynamic strength of one-rep max for upper and lower body, countermovement jump, and throwing velocity were measured. The strength group showed a significant increase in countermovement jump height (2.38 cm; 6.9% change; ES= 0.48). One-rep max also increased significantly for squat (11.06 kg; 14.21% change; ES= 0.67) and bench press (9.06 kg; 10.53% change; ES= 0.66) in the strength group.

Muscle soreness

The results for the study by Arazi et al. (2016a) was described for the effects on power movements and muscular strength subtopic section, but the study also measured muscle soreness after each of the three different time periods at 24 hour (hr), 48 hr, and 72 hr post exercise. Measurements taken at 24 h and 48 h post-exercise had a group x time interaction that showed to have a significantly greater increase in muscular soreness for the firm ground group in comparison to the sand and aquatic group. The study found no significant changes in muscle soreness for the aquatics group.

Tofas et al (2008) did a study with eighteen untrained men that were split into an experimental group (*n*= 9) and a control group (*n*= 9) who rested during the study. The researchers were testing the effects of plyometric exercise on DOMS (muscle damage) and collagen breakdown. Measurements were taken seven days prior to the test, as well as 24 hr, 48 hr, and 72 hr after testing. There were no changes in ROM for both groups. The baseline numbers were compared to the changes after the time periods, which after a 48 hr period resulted in a significant increase in DOMS and creatine kinase levels increases significantly during the 48–72 hr measurement time.

Wertheimer, Antekolovic, & Matkovic (2018) tested the different muscle damage indicators during an eight-week plyometric training program for aquatic and land plyometric exercise. Sessions occurred twice a week, for 16 identical sessions in both groups. The two groups of twenty physically active men (*n*= 10, group on land; *n*= 10, group in water) were tested by their blood for lactate dehydrogenase (LDH), creatine kinase (CK), and serum urea (SU) four times, one hour before and after first training session, and 24 hr after the first and last training session. The exercises performed consisted of bilateral and unilateral movements such as: Ankle jumps, Countermovement jumps; Drop jumps (30 cm), Single leg ankle hops, Single leg countermovement jumps, Single leg forward jumps, Alternate-leg bounds, Single leg lateral hops, and Lateral bounds. The aquatic group performed in water at hip level with their arms on the hips, while the land group performed movements in a gym hall with their hands on the hips as well. The study eliminated momentum assistance from arm swing motion for both groups. The results of the experimental group on land show differences before and after both plyometric trainings (1st – 277.33±101.93 U/I (pre) – 551.74±283.50 U/I (post); 2nd – 250.17±64.89 U/I (pre) – 515.59±327.74 U/I (post)), probably because of high eccentric contraction during the plyometric training. The results of the experimental group in water also show significant differences before and after both plyometric trainings, but with somewhat lower CK levels (1st – 263.89±119.08 U/I (pre) – 486.21±369.92 U/I (post); 2nd – 226.51±101.02 U/I (pre) –

310.73±136.82 U/I (post)) No differences in CK activity or LDH were observed between the experimental groups. No differences for LDH before and after the first and last plyometric training session. The SU only showed significant differences after the first session in the land group. No significant differences between the two groups for SU. Motor performance was shown to be greater for both groups, but the aquatic group had the greatest improvement.

Impact forces

Ruschell et al (2016) conducted a study testing the ground reaction forces and contact duration for the contact phase of a drop jump exercise. The study consisted of 22 male athletes ages 19.1 $\pm$ 3.7 year. The subjects were set at hip height on land and water to perform three maximum depth jumps. Peak force was tested using a 2-D waterproof electrogoniometer, acquisition system ADS2000-IP and TeleMyo 2400 TG2 and a signal synchronizer, where the braking and propulsion sub-phase was measured. Peak force braking was decreased by 41.8% and peak force for propulsion was decreased by 23.8%, for the in water trials.

Colado et al (2010) performed a study over vertical ground reaction forces for one and two leg squat jumps in an aquatic medium and on dry land. The study consisted of 12 female handball players ages 16 $\pm$ 0.74 and compared the different reaction forces for the two groups. The subjects were trying to avoid fatigue while attempting 3 of each jump. The aquatic medium group showed a significant difference for impact forces and peak concentric forces for both jumps exercises. Impact forces for jump with two legs on dry land were 2,669 $\pm$ 1121.42 N and the aquatic group 1,065.57 $\pm$ 555.33 N. The peak concentric forces were higher in the aquatic group for two legged jump (1,046.76 $\pm$ 263.45 N) with the possibility of natural resistive factors from the water, while the land group jump was only 838.14 $\pm$ 189.48 N.

Donoghue et al. (2011) had a study with 18 male participants ages 23 $\pm$ 1.9 year that tested the different impact forces of plyometric exercise on dry land and in an aquatic setting. The male subjects performed ankle hops, tuck jumps, countermovement jump, single-leg vertical jump, and a drop jump from 30 cm. a force plate was used to test peak impact force, impulse, rate of force development, and time to reach peak force of landing phases. Both the aquatic and land group were almost identical for reaction forces during the single-leg jump, with the land group having a slightly higher value. The aquatic setting significantly reduced the impulses by 19%-54% in all of the exercises and categories. The aquatic setting also had a significant reduction for rate of force development by 33%-62% for the ankle hops, tuck jumps, and countermovement jumps. The impulses measured for countermovement jump and drop jump was the only category to have a moderate effect, while all other impulses tested for the exercises not mentioned had a large or very large effect. The rate of force development showed to have a large effect for countermovement jumps and the ankle hops showed a moderate effect.

Discussion

This literature review used twenty sources from 2008-2018 measuring the differences in power movements in comparison to land and aquatic settings, muscle soreness, ground surface type, cross-training methods, strength, improvement of athletic performance, volume effects, and impact forces. The major findings for cross-training athletes (Haff, 2008a; Haff, 2008b) in a strength program with aquatic settings showed to have better benefits for the participants than just traditional methods alone, but no other cross-training studies were conducted to compare. Haff, G. (2008b) mentions that the style could be beneficial to cross-train athletes and would provide an opportunity for athletes who have reached a plateau in their training. Two studies that were conducted over a six-week period (Fonesca et al., 2017; Ploeg et al., 2010) both showed similar increases in VJH for water and land groups, but in the study by Ploeg et al. (2010) the volume was doubled in the aquatic two group and increases were significantly higher than the aquatic group that did similar volume as land plyometric training. This evidence could demonstrate that increasing the frequency, duration, or volume of plyometric training in water could lead to larger increases over longer periods of time when land training starts to wear and tear the joints and athletes begin to experience overtraining symptoms or hit a plateau. Ramirez et al. (2015) states that aquatic-based plyometric exercise has positive impacts when it comes to explosive strength and the aquatic training setting could be beneficial to rehabbing the senior population. The same could go for the rehabilitation of athletes as well, or detraining phases in strength and conditioning programs, while still keeping the intensity high, but with less force put onto the body. The evidence for postmenopausal women was significant, but no other study was found with similar populations to compare with. Even though plyometric training is a hard exercise to perform for older populations due to high impact and intensity, further studies could be conducted in the pool, because Ramirez et al. (2015) shows aquatic plyometric training will still help with increasing muscular strength. Elderly populations need to have strength, and water plyometric training could promote that, along with the supplementation of dynamic balance exercises to help with their equilibrium, which the buoyancy effects of the water help improve, as mentioned in the study using basketball players by Arazi & Asadi (2011b). Arazi & Asadi's (2016a) study on acute effects of bouts of plyometric training on different ground surfaces showed the firm ground group was significantly higher for muscle soreness 24 hr-48 hr post-exercise and the aquatic group had no change in soreness during each testing period. Arazi & Asadi (2016a) also mentions that VJH returned to baseline 72 hr post-exercise, while the firm group remained significantly lower at the 72 hr post-exercise testing period. The study by Arazi

& Asadi (2016a) should further research the acute effects over a period of time to see if these numbers begin to get lower for land training and remain constant for water, furthering the evidence of the effects of buoyancy. There were two studies testing impact forces (Donoghue et al., 2011; Ruschell et al., 2016) showing the aquatic setting significantly reduced the forces put on the body during plyometric training in comparison to land groups. Some studies lacked statistical evidence but confirmed there were similar increases to power movements for aquatic and land plyometric training (Arazi & Asadi, 2011b; Ceran et al., 2011), but this was a limitation to the results being proposed. No clear structure for the program was mentioned, but the studies used similar age groups and number of participants. The majority of studies reviewed were limited to male population ages 14-30, so further studies need to be conducted on women to avoid a gender bias. Significant improvements were found in the literature for women, but not enough to evaluate the benefits of aquatic plyometric exercise on power. Further recommendations for cross-training athletes in the water need to be tested to better understand why aquatic cross-training could be beneficial, with quantitative data, rather than trusting a literature review by previous research. The studies could focus on increasing frequency for an aquatic group during in-season training, while the land group could perform the normal frequency the strength and conditioning program already has established. Researchers could measure VJH pre and post, measure the impact forces the ground surface has, and also focus on delayed onset muscle soreness 24-72 hr after each training session, which is the same concept by which muscle damage was measured in the study by Arazi et al. (2016a) on acute effects of plyometric training on different surfaces. The combination of these studies for VJH, muscle soreness, and impact forces could be put together to create a study design in the future to focus on the length of study, volume, intensity, muscle soreness after every session, and the impact on the body. The problem to be addressed is can power have a positive effect in athletic performance in a long-term setting and maintain that state when the effects of buoyancy are considered. The length of participation is key, as adaptations will occur throughout the program. Volume will be another focus during sessions in order to properly analyze increases in VJH during high volume aquatic training. Buoyancy is also a key factor to the reduction of muscle soreness and the impact forces on the joints.

CHAPTER 3: METHODOLOGY

Participants

The participants for this study were recruited at Mercy Fitness Center Edmond I-35 and the University of Central Oklahoma through email blast. A recruitment flyer was made to promote the study providing the qualifications: must be ages 18-40, free from any major lower body injuries for the past 3 years, no exercise limitations that prevent individuals from exercising, and participants must also be performing resistance training at least twice a week for the past 12 months. These qualifications were made for the high intensity and high impact land training can have on the body, along with the technique and strength needed to be able to perform the plyometric exercises. Both female and males were encouraged to participate in the study. A brief description was mentioned on the flyer for what is to be expected, including study length and session duration. An approval from the General Manager of the Mercy Fitness Center via email was provided to allow the recruiting and testing process over the eight-week intervention. An ANOVA with repeated measures was the statistical test ran to compare pre-training and post-training results for VJH (vertical jump height), hang time, and body composition in both the LPT (land plyometric training) group and CG (control group). A Cohen's *d* effect size of .59-.69 was found in a study by Stemm & Jacobson (2007) which compared land and aquatic plyometric programs among 20 participants. Therefore, the goal for this study was 20 participants. However, only 13 participants completed this study.

Instruments

All measurements were taken at the training site at Mercy Fitness Center. The instruments used for body fat percentage measurements were the Lange skinfold calipers during pre- and post-measurement days. A Just Jump Mat™ will be needed as well to measure vertical jump values. The Just Jump Mat™ calculates the VJH by scoring the time in the air from when the participant jumps to when they land back onto the pad and the device provides a VJH out of the time in the air score. The Just Jump Mat™ is a useful tool which is valid and reliable for calculating VJH performance according to Pueo et al (2020). In this study, the researchers used intra-class correlation coefficients (ICC) to measure reliability and Bivariate Pearson's correlation coefficient (*r*) to measure validity. The study found the correlations between the two jump pads were almost perfect values for reliability (ICC= 0.999-1.000) and validity (*r*= 0.999) (Pueo et al., 2020). A weight and height measurement tool were used to record participant's height and weight before and after the intervention. The researcher wanted to choose the best method for measuring body fat percentage, not only for the best accuracy, but also for reducing the number of limitations in this process. Bioimpedance calculators are sensitive to many factors, such as food, exercise, alcohol, tobacco, etc., while skinfold calipers require no exercise before measurement and plenty of hydration as well. The bioimpedance calculator has a test-retest of 95% and a validity of $\pm$ 3.5% according to an article for validity and reliability of bioelectrical impedance analysis (Aandstad et al., 2014). A study by Hayes et al. (as cited in Heyward & Gibson, 2014) says a 12-site skinfold measurement test has similar values as magnetic resonance imaging. Lohman (1992) stated (as cited in Heyward & Gibson, 2014) body fat percentage can be accurately estimated within $\pm$ 3.5% using skinfold equations and techniques. Two other studies also show the bioimpedance calculator reading significantly higher body fat percentages than skinfold calipers (Hetzler et al 2006; Otte, 2017). Therefore, the researcher has determined it is best to use Lange skinfold calipers for the best results as they are a skilled practitioner in this area. A Physical Activity Enjoyment Scale (PACES) was used to measure and compare the enjoyment of a LPT program. The PACES scale ranges scores from 18-126. This scale rates the enjoyment of the physical activity performed during the intervention with higher score equaling more enjoyment and lower scores representing less enjoyment felt by the participants (Kendzierski & DeCarlo, 1991).

Procedures

The study consisted of measuring pre-test variables, eight-week land plyometric intervention, and post-test variables to compare effects of the LTP group and CG. Test days also consisted of recording the participant's confidential code of identity, weight, height, body fat percentage, age, and gender. A familiarization session was conducted the same day as first testing day to assure participants understand and are comfortable with the exercises prior to the intervention. The familiarization session was used to limit the learning effects of proper techniques for this intervention. Participants were selected randomly into two groups: land plyometric training (LPT) and control group (CG). Testing occurred one week before and after the eight-week intervention. Training days were twice a week with one day of rest in between training days. Participants performed box jumps, squat jumps, depth jumps, single-leg hops, broad jumps, jumping lunges, lateral bounds, power skips, combinations of jumping exercises, and transverse (change of direction) box jumps. Training days consisted of a 10-minute warm-up, 35-45-minute of plyometric training, and a 5-minute cool down/stretch. The land plyometric program was referenced for repetition and set progressions from the High-Powered Plyometrics book by Radcliffe & Farentinos (2015) using the continuum training for track sprinters, jumpers, and hurdlers as a guide to properly progress and choose explosive exercises to improve VJH. The volume was periodized every 2 weeks to adjust for the training adaptations the participants experienced in phases 1-4, with reps ranging from 3-16, 12-24 total sets, and rest intervals of 30-60 seconds. Phase 1 consisted of an average of 6.5 exercises, 12.5 sets, and reps ranging from 3-

10 between the two days performing plyometric training. Phase 2 averaged 8.5 exercises, 18.5 sets, and reps ranging from 3-12. Phase 3 averaged 10.5 exercises, 19.5 sets, and reps ranging from 3-16. Phase 4 averaged 11.5 exercises, 23 sets, and reps ranging from 3-16. The researcher made sure to ask participants each time they met how they felt during and after exercise sessions to ensure accuracy of exercise progressions. This data was not recorded in statistical analysis but was for personal use by the researcher to make adjustments accordingly if needed. Plyometric boxes 6-24 inches were used to aid in progression of exercises and improvements.

Design and Analysis

The research design was an experimental randomized-controlled trial. Participants were randomly assigned to LPT or a CG. Values for VJH were measured and presented in inches from the Just Jump Mat™; body weight was presented in pounds, hang time in seconds, and body fat as a percentage. Repeated-measures ANOVA was used to analyze any differences in the pre-test and post-test values between and within groups. Cohen's *d* was used to calculate effect sizes. All statistical tests were performed on the IBM® SPSS® statistical analysis program.

CHAPTER 4: RESULTS

The purpose of the study was to investigate the effects of plyometric exercise in a land environment on VJH (vertical jump height), hang time, and body composition. A CG (control group) was utilized for comparison. Physical activity enjoyment was also recorded for the LPT (land plyometric training) group after the eight-week intervention was complete. The primary research question asked, “is a control group or a land plyometric group more effective for increasing VJH?” The null hypothesis stated the CG will result in no difference in VJH in comparison to the land group. The researcher hypothesized LPT would be a more effective method for increasing VJH. Second, the researcher hypothesized the LPT group will be a more effective method to improve hang time and decrease body fat percentage. Significance was set as $\alpha = .05$. An ANOVA with repeated measures was used to determine the changes over time between pre-testing and post-testing. Effect sizes were calculated using Cohen’s *d*.

Descriptive Statistics

The population for the research study consisted of 13 participants (10 males: 23.4±4.01 years and three females: 21.33±2.52 years). The study was split into a LTP group (*n*= 6; 5 males, 1 female) and a CG (*n*= 7; 5 males, 2 females) to compare the effects on VJH over time.
Body weight was measured in pounds (lbs). Two outliers were found, one for pre-hang time and one for pre-vertical jump in the land group for the same female participant. This participant was also the only female participant in the LPT group. The female participant’s pre-vertical jump was 12 in and her hang time was .49 s. These values are within the normal range for average jump height and hang time in females. The outlier was not removed because of the likelihood of the difference in performance was due to biological sex, muscle fiber type, and jumping abilities.

The M±SD for pre vertical jump in the land group was 21.68±5.13 in and hang time was .66±.087 s. Table 1 includes a list of descriptive statistics for all variables among both groups.

Vertical Jump

To measure the changes over time for VJH from pre-testing to post-testing, an ANOVA with repeated measures was used. Significance was set at $\alpha = .05$. VJH is scale data measured in inches. The M±SD in the CG for pre-vertical jump was 21.27±5.15 in and a post-vertical jump of 21.67±4.33 in. The land group had a M±SD 21.68±5.13 in during pre-testing for vertical jump and 22.88±4.58 in during post-testing. Descriptive statistics can be found in Table 1. Both groups had normal distribution in all variables except in the land group, as the pre-vertical jump was negatively skewed. This was likely due to the outlier at pre-test for vertical jump. A small ES was found for changes in vertical jump over time in both the land group ($d = .23$) and control group ($d = .07$). There was a significant time effect, providing evidence of improvements in vertical jump among all groups ($F_{(1,11)} = 5.088$, $p = .045$). However, no significant effect was found for the time and group interaction ($F_{(1,11)} = 1.272$, $p = .283$). Inferential statistics for each variable can be found in Table 2.

Body Composition

Data was also analyzed to observe changes in body composition over the eight-week intervention. Body composition consisted of three difference measurements: body fat percentage, weight, and the total body fat in mm using skinfold calipers. Body fat changes in millimeters for the skinfold calipers had little to no change, therefore, these statistics were not included in the results, but the data can be found in Table 1. Body fat percentage is the main variable for this category, but other variables were included to detect small changes over time. An ANOVA with repeated measures was conducted with descriptive and frequencies statistics reported.

Significance was set at α= .05. All data was normally distributed, and no outliers were present. All body composition variables were scale data, measuring body fat in percent, weight in pounds, and skinfold measurements in mm. The M±SD for body fat percentage for pre-testing in the land group was 12.98±7.88% and the CG was 15.32±7.02%, while the post-test was 12.65±7.25% for land and 16.2±5.91% for the CG. Table 1 displays all descriptive statistics for these variables. ES were small negligible for both groups. There were no significant differences found for body composition in all three categories of body composition, however, a negative effect size was small (ES= .04) for body fat percentage was shown for the LPT group. This data demonstrates the decrease in the participant's body fat percentage of the LPT group from pre-testing to post-testing measurements. Body fat percentage was not significant for time ($F_{(1,11)}$= .743, $p > .05$) or time by groups ($F_{(1,11)}$= 3.725, $p > .05$). Inferential statistics and effect sizes can be found in Table 1.

Hang Time

Hang time was also measured to determine the effects of the plyometric intervention. Changes over time were put into SPSS using an ANOVA with repeated measures. Descriptives and frequencies were also reported (Table 1). Significance was set at α= .05. One outlier was present for pre-hang time; however, the data was included. Data was normally distributed for the CG during pre-testing and post-testing, but the data was negatively skewed for the land group during pre-testing (Skewness= -1.950) and post-testing (Skewness= -1.036). This could be due to the single outlier in pre-hang time. The variable hang time is scale data measured in seconds. The M±SD for hang time for pre-testing was .660±.087 s in the land group and .657±.085 s in the control group. At post-test both the land (M=.685±.074 s) and control groups (M=.664±.068 s) reported an increase in hang time. A small ES was reported for both the land (*d*= .29) and control (*d*= .09) groups from pre to post-test. Hang time did change significantly over time among both groups ($F_{(1,11)}$= 6.026, *p*= .032 (Table 2 & Figure 3) No interaction occurred when analyzing changes between groups over time ($F_{(1,11)}$= 1.860, *p*= .20).

Physical Activity Enjoyment Scale (PACES)

Physical activity enjoyment was measured with the Physical Activity Enjoyment Scale (PACES). The questionnaire consisted of 18 questions, asking participants to rate their feeling at the moment for the physical activity in which they have been participating in. The scale ranged from a total of 18-126, with higher scores indicating higher enjoyment for that activity. The average score on the PACES scale for the eight participants was 107.7±16.87, with the highest enjoyment being at 125 and the lowest enjoyment being at 86. The control group was not given the PACES scale due to performing no activity during the eight-week intervention.

CHAPTER 5: DISCUSSION

This study was conducted to determine whether an eight-week intervention performing plyometric exercise in a land environment would have an effect on vertical jump height (VJH), body composition, and hang time, in comparison to a control group (CG). Researchers hypothesized improvements in VJH based on the understanding that athletes improve power output by training the body to be powerful by performing explosive moves which requires fast twitch fibers and a stretch-shortening cycle. The stretch-shortening cycle was integrated by teaching participants how to properly double jump in exercises that required such technique to perform maximal output in minimal time.

Vertical Jump

The main variable of this study was VJH. Over the eight-week intervention the researcher periodized the plyometric training program every two weeks to help participants with adaptations throughout the program, increasing volume, and adding/progressing new exercises. Norm values for VJH in the American Council on Exercise (ACE) personal trainer manual are as follows: Males- >28 inches (in.)= excellent, 24-28 in.= very good, 20-24 in.= above average, 16-20 in.= average, 12-16 in.= below average, 8-12 in.= poor; Females- >24 in.= excellent, 20-24 in.= very good, 16-20 in.= above average, 12-16 in.= average, 8-12 in.= below average, 4-8 in.= poor (Bryant & Green, 2010). In this study, LPT group increased by 1.2 in (5.54% increase) and the CG increased by 0.4 in. (1.88% increase). The researcher found the LPT group outperformed the CG by a mean of 0.8 in. (Table 1) in VJH from pre-test to post-test measurements. While this comparison is not significant, it slightly supports the researcher's hypothesis, even though the LPT group had lower increases (*M*= 1.2 in increase) over the intervention than most other studies cited. The VJH male participants in the current study (*n*= 5; 22±3.32 years) were considered above average from their mean of 22.08 in. at pre-test and 23.2 in. at post-test. The female participant (*n*= 1; 21 years) ranked borderline average/below average from their VJH of 12 in at pre-test and improved to average (15.4 in) at post-test. Several research articles cited in this study had increases for VJH, such as a study by Fonesca et al. (2017) with male soccer players (16±0.5 years) who ranked below average (15.81 in.) at pre-test and average (18.22 in.) at post-test (2.4 in. increase). Bavli (2012) had a six-week study for basketball players (16.3±1.2 years) who ranked average (18.9 in.) at pre-test and above average (20.47 in.) at post-test (1.8 in. increase). Fabricius (2011) conducted a seven-week intervention with rugby players (16.5±0.8 years) who ranked average (19.55 in.) at pre-test and above average (20.93 in.) at post-test (1.38 in. increase). A decrease of 0.51 in. was found for VJH in a six-week study conducted by Ploeg et al. (2010) where untrained healthy individuals (*n*=39; 16 males 21.8±2.3 years, 23 females 22.4±3.5 years) ranked average (19.45 in.) at pre-test and post-test (18.94 in.). Female statistics were not available for this study because the researcher used the average increases as one variable instead of dividing male and female participants. This data demonstrates how individuals of different ages and fitness levels can vary the increases overtime in VJH. Decreases in VJH could possibly be due to limitations and delimitations the study had for fitness level, experience, adherence to exercise instruction or not exercising outside of study, environment, and soreness/injury due to participant being untrained and possibly unprepared for vigorous exercises. One source had a lower increase in VJH in a study by De Villarreal et al. (2009) where 30 professional water polo players (23.4 ± 4.1 years) trained for six weeks three times a week. The land group increased their VJH from 15.47 in at pre-test to 16.41 in. at post-test (0.94 in). Most professional water polo player have likely developed slow twitch muscle fibers over the many years of swimming for their sport, therefore this could be one reason why VJH did not increase as much as the current study by the researcher or other studies cited. The closest age group and sample size to the current study was conducted by Ceran et al. (2011). He compared land and aquatic plyometric exercise by training college students (*n*= 13; 21.77 ± 1.42 years) three times a week for four weeks and increased their VJH by 1.58 in. on land setting and 1.85 in. for aquatic setting. These different increases can also vary from frequency of exercise (days per week), duration (length of study), intensity (difficulty of exercise program), volume (total amount of weight lifted), exercise selection, or the specific athlete, meaning one could be more or less trained than the other. The current researcher also noted the two highest individual increases by participants in VJH for both groups, in which the land group had a participant increase by 3.4 in at post-testing and the individual in the CG who increased by 2.3 in. It should be noted four out of seven participants in the CG reported a decrease in VJH, while only two out of six participants decreased in the land group. There was one outlier found in the pre VJH and the only female participant in the LPT group. The outlier may be explained by biological sex characteristics, muscle fiber type, and jumping abilities which may cause differences in power output among males and females. The study also found that there was a significant data in the effect over time for all groups *p*= .045, with the land group increasing more over time than the CG. This is significant and helpful to research because this comparison shows the differences of training specificity for individuals. The land group was focused on solely plyometric exercise, while the CG was focused on their own routines, which consisted of weightlifting, running, biking, swimming, etc. The land group also weight lifted and did cardio on their own, but the difference between the two groups is the land group trained their bodies to be powerful, quick, and adapt, meanwhile, an individual cannot get the type explosiveness and quickness from traditional weightlifting, although, maybe through Olympic lifting, but the participants in the control group were did not report that type of training.

Body Composition

The researcher also examined changes in body composition over both groups. Over the eight weeks, body fat percentage in the land group went from a mean of 12.98% to 12.65%. A negative effect size (*d*= .04) was small for body fat changes but confirmed a decrease in body fat percentage for the LPT group. The CG increased body fat percentage from 15.32% to 16.2%, with the highest increase by one participant of 1.7% and the largest decrease in body fat percentage of 1% by another participant. The land group participant with the largest decrease in body fat percentage was 2% and the highest increase was 1.7% by another participant. It should be noted that four out of the seven participants in the control group increased their body fat percentage, while only one in the land group increased out of six. Changes in weight were not significant. It is meaningful to note some land group participants decreased their body fat percentage and increased muscle mass or other LPT participants maintained the same body fat percentage and increased muscle mass with the addition of participating in plyometric exercise in comparison to the CG. Meanwhile, five out of seven participants in the CG had a change in their body composition where they increased their body fat percentage over time and did not change their lean body mass. The researcher knows this by calculating the amount of lean mass tissue and fat mass with total body weight for convenience of equipment. The researcher would need equipment such as a DEXA (dual-energy x-ray absorptiometry) scanner to obtain accurate information about body composition changes. The study acknowledges the lack of change over time for body composition, because there was no significance found (significance set at $\alpha = .05$) for body fat percentage ($p = .080$), only a slight glimpse of decreasing data. You would expect to see an individual to see significant changes over time in body composition, but in this case, the amount of exercise performed in the study along with the limitation of participants exercising outside of the study may have limited our outcomes for body fat percentage being decreased.

Hang Time

Hang time was another variable provided by the Just Jump Mat™. The LPT increased their hang time by an average of .0267 seconds (s) and had a mean of .66 s at pre-test and .685 s at the post test. The CG increased their hang time by an average of .0057 s and had a mean of .657 s at pre-test and .664 s at post-testing. It is meaningful to note that four out of seven participants in the CG had a negative decrease in hang time, while only participant had a negative decrease in hang time in the land group out of six. The researcher's data found a significant change over time among both groups p= .032. There is not enough research out there to conclude hang time increases over time, but the LPT group had significant increases for both VJH and hang time. Pre-testing for hang time was negatively skewed in the LPT, in which the participant is the only female in the LPT. This outlier occurs because her hang time was significantly lower than the males at pre-test and in general, the majority of males have a higher power output than females. Not only will males jump higher than the majority females, but also stay in the air longer as well because of the height men can jump to in comparison to women from the data collected.

Physical Activity Enjoyment Scale (PACES)

The PACES scale helped the researcher determine if the exercise performed was enjoyable over the eight-week LPT (land plyometric training) intervention. The scale scored from 18-126. The average score for the LPT group was 107.7±16.87 and was compared to a study by Kendzierski & DeCarlo (1991) in which they compared enjoyment of activity for riding an exercise bicycle and jogging with external focus and controlled conditions. In this study the M±SD in the controlled conditions group ended up being 96.27±17.98 and 81.08±21.08 for the external experimental group. This comparison can possibly demonstrate the type of exercises performed and the setting they are performed in, can affect the enjoyment of certain physical activity. The researcher believes this plyometric study is more enjoyable because the type of exercise is more interactive for the participant to perform. LPT is said to require more skill and provide a greater challenge than traditional exercise. The researcher also provided new exercises every two weeks, which may have added to the diversity and enjoyment of the program. Furthermore, the relationship between the researcher/trainer that was developed with participants could have had a positive impact on the enjoyment scores, but the research for such comparisons has not been conducted in previous studies, which could be studied in future research to find evidence.

Summary

The study found data that was significant enough to show the researcher the effects on vertical jump height (VJH) in a land environment. Participants wanted to adhere to the instructions given by the researcher, but limitations of school, work, emergencies, and illnesses affected the participant's adherence to exercising as regularly as they were before the intervention. There are external factors in which studies cannot always control and are expected to come up in research. The land plyometric training (LPT) group tried to have better results with body fat percentage, but some participants did not adher to exercise outside of the research study. Participants in the LPT group missed an average of two sessions during the eight weeks, but no one went over the three-absence limit. Some participants mentioned getting off track with dieting and exercise habits, which could impact body fat percentage changes. On testing days, participants mentioned being sore from outside activity, which may have impacted the individual test results. The researcher could not control if participants prevent from performing plyometric exercise outside of the study or keeping up with their weekly exercise routines. Another limitation was a small sample size, which might skew data or make it difficult to achieve enough power to find significance. More participants in a future study could possibly help improve the findings. This group was also already a highly fit group, which may have mitigated the amount of change possible over an eight-week time period. A 12-week study by Kamalakkannan et al. (2011) had 36 volleyball players, also highly fit athletes, which had two separate groups performing exercise in an aquatic environment, one group with weights had an increase of 2.43 inches and the group without weights increased by 1.24 in. in VJH. The statistics not only show significant data for aquatic plyometrics, but also could possibly correlate with other studies mentioned previously for trained athletes having significant increases for VJH in comparison to the studies that showed decreases in VJH in untrained individuals, depending upon the sport as well. This study conducted by the researcher has shown a plyometric exercise program on land can have a positive effect on VJH, hang time, and body composition, but more time may be needed to detect significant changes. It also demonstrates that all training could have a beneficial impact on maintenance of performance and body composition measures, while also having a positive change in body composition. Future research should also be of longer duration, fitness levels, and focused on different environments for plyometric training such as water, sand, and resistance bands/weights, to see the effects over time from each group and improve the fitness world and athletic performance of individuals.

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Tables and Figures

Table 1
Descriptive statistics and Effect Sizes for 8-week Plyometric Exercise Intervention for Land and Control Groups.

	Land			Control		
Variable	Mean	SD	ES	Mean	SD	ES
VJ			.23			.07
Pre	21.68in	5.13in		21.27in	5.15in	
Post	22.88in	4.58in		21.67in	4.33in	
Hang Time			.29			.09
Pre	.660s	.087s		.657in	.084in	
Post	.685s	.074s		.664in	.068in	
BF%			.04			.13
Pre	12.98%	7.87%		15.32%	7.01%	
Post	12.65%	7.24%		16.2%	5.91%	
Weight			.03			.17
Pre	169.15lbs	21.46lbs		182.14lbs	39.99lbs	
Post	169.78lbs	19.44lbs		182.8lbs	41.2lbs	
SFC Totals			.05			.18
Pre	43mm	19.65mm		47.21mm	13.86mm	
Post	42mm	18.26mm		49.64mm	12.78mm	

Note. SD= Standard Deviation; ES= Effect Size; VJ= Vertical Jump; BF%= Body Fat Percentage; SFC= Skinfold Caliper Totals.

Table 2
Repeated Measures ANOVA Results for Within Groups Variability from Pre-test to Post-Test for Measures of Vertical Jump, Hang Time, Body Fat Percentage, Weight, and Skinfold Caliper Totals.

Variable	SS	*df*	MS	F	*p*
VJ					
Time	4.135	1	4.135	5.088	.045*
Time*Group	1.034	1	1.034	1.272	.283
Hang Time					
Time	.002	1	.002	6.026	.032*
Time*Group	.001	1	.001	1.860	.200
BF%					
Time	.468	1	.468	.743	.407
Time*Group	2.345	1	2.345	3.725	.080
Weight					
Time	2.69	1	2.69	.780	.396
Time*Group	.001	1	.001	.000	.987
SFC Totals					
Time	3.297	1	3.297	.579	.463
Time*Group	18.989	1	18.989	3.336	.095

Note. SS= Sum of Squares; *df*= degrees of freedom; MS= Means Square; F= ratio; *p*= significance; VJ= Vertical Jump; BF%= Body Fat Percentage; SFC= Skinfold Caliper Totals.
*indicates significance (p<.05)

Changes in VJH Over 8 Weeks Between Groups

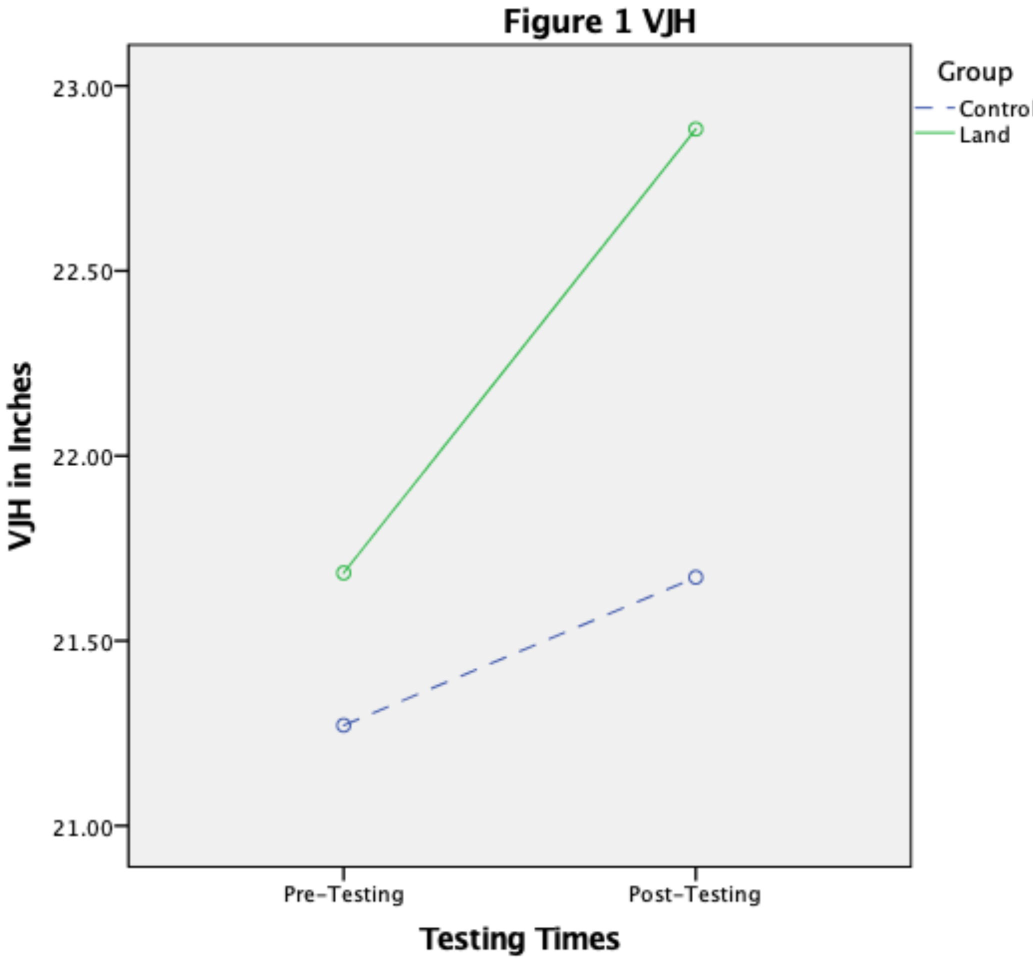

Figure 1.1. A line graph representing the change over time for VJH in inches from pre-testing to post-testing during an eight-week plyometric intervention.

Changes in Body Composition Over 8 Weeks Between Groups

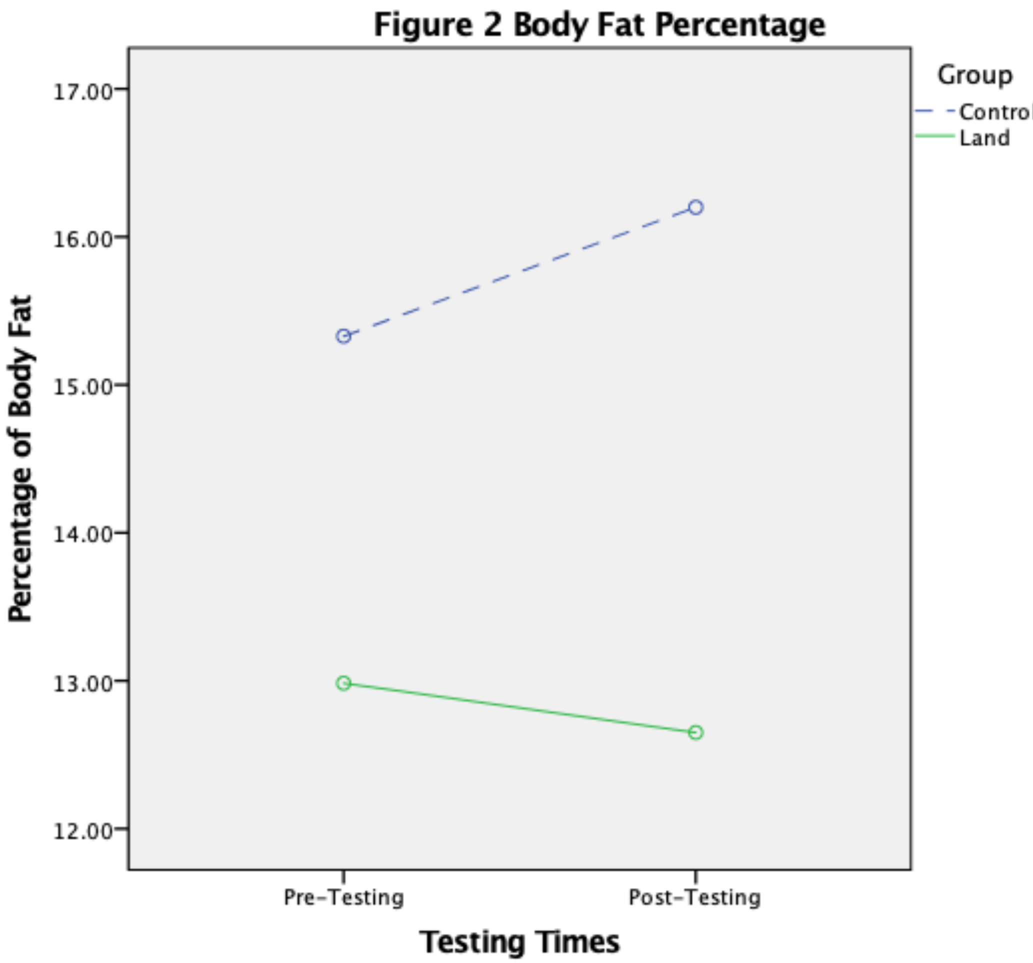

Figure 2. A line graph representing the change over time for body fat in percentages from pre-testing to post-testing during an eight-week plyometric intervention.

Changes in Hang Time Over 8 Weeks Between Groups

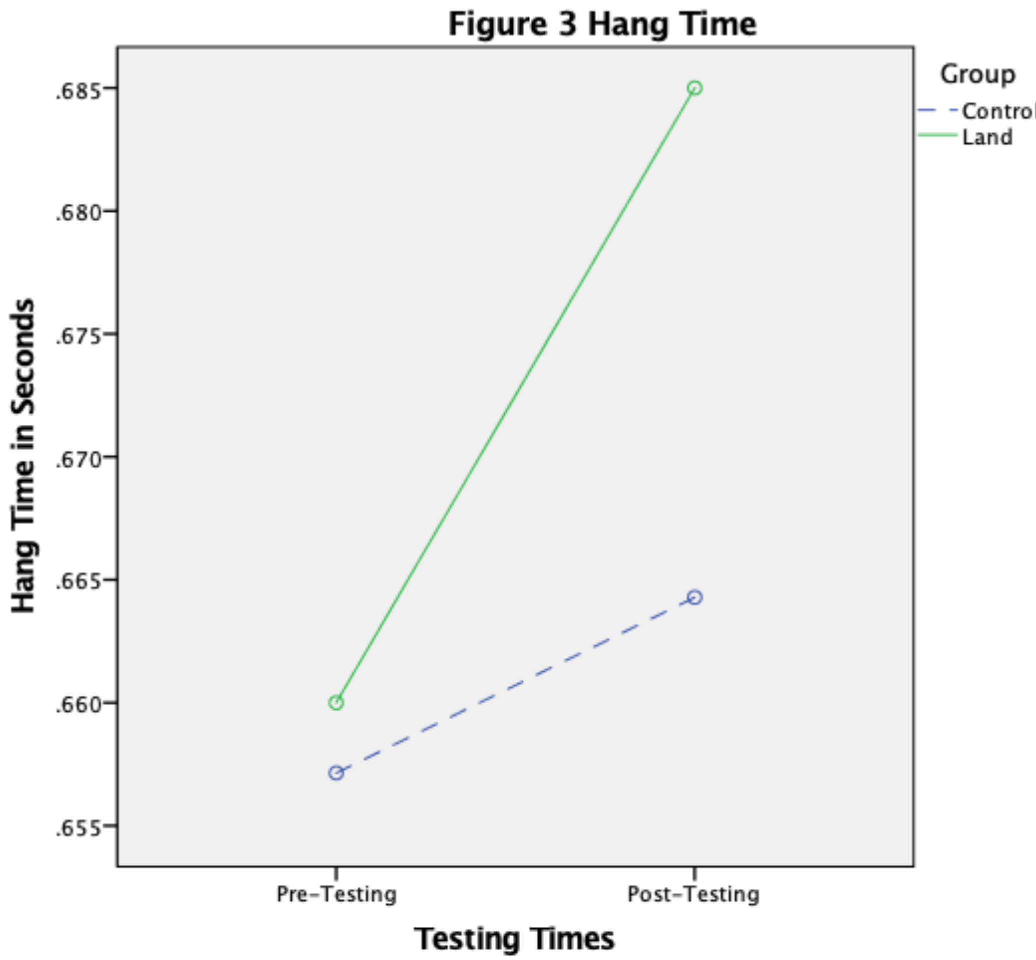

Figure 3.1. A line graph representing the change over time for hang time in seconds from pre-testing to post-testing during an eight-week plyometric intervention.

Appendix A – Informed Consent Form

Informed Consent Form

Research Project Title:

A Comparison of Plyometric Training on Power Benefits, Body Composition, and Enjoyment

Researcher:

Landon Paul Jackson

Purpose of this study

The purpose of this study is to compare the effects of plyometric training in a land environment on vertical jump height, hang time, and body composition during an eight-week plyometric intervention.

Procedures:

The study will consist of measuring pre-test vertical jump height, eight-week land plyometric intervention, and post-test vertical jump height to compare effects of the land plyometric training group and control group. Test days will also consist of recording the participant's confidential code of identity, hang time, body fat percentage, weight, height, age, and gender. The physical activity enjoyment scale (PACES) will be used to measure enjoyment at the conclusion of the intervention. A familiarization session will be conducted the same day as first testing day to assure participants understand and are comfortable with the exercises prior to the intervention. The familiarization session will be used to limit the learning effects of proper techniques for this intervention. Participants will be selected randomly into two groups: land plyometric training and control group. Testing will occur one week before and after the eight-week intervention. Training days will be twice a week with one day of rest in between training days. Participants will perform box jumps, squat jumps, depth jumps, single-leg hops, broad jumps, jumping lunges, lateral bounds, power skips, combinations of jumping exercises, and transverse (change of direction) box jumps. Training days will consist of warm-up, plyometric training, and a cool down/stretch.

Expected length of participation:

The study is 10 weeks in length. Participants will meet twice a week for eight weeks, with a pre-test measurement of vertical jump height, hang time, body fat percentage, weight, height, age, and gender, one-week before intervention, and a post-testing measurement of vertical jump height, hang time, and body fat percentage to compare differences over study. PACES scale will be used at post-test to rate enjoyment of the physical activity. Training days will start with a 10-minute warm-up of foam rolling, jogging, and dynamic stretches. Training sessions will be 35-45-minute of plyometric training and volume were periodized every 2 weeks to adjust for the training adaptations the participants experienced in phases 1-4, with reps ranging from 3-16, 12-24 total sets, and rest intervals of 30-60 seconds. A 5-minute cool down and stretch will occur at the end of every session to assure for proper blood return and to prevent blood pooling from the lactate threshold that will be achieved during sessions. The researcher made sure to ask participants each time they met how they felt during and after exercise sessions to ensure accuracy of exercise progressions. This data was not recorded in statistical analysis but was for personal use by the researcher to make adjustments accordingly if needed. Plyometric boxes 6-24 inches were used to aid in progression of exercises and improvements.

Potential benefits:

The benefits will include an opportunity to increase vertical jump height, generate higher explosive power, change their body composition, be a part of a research study, work with a personal trainer, and learn new/alternative types of exercises to use in the future.

Potential risks or discomforts:

The amount of stress will be high in participants that are a part of the land plyometric training group due to the high impact force plyometric training on land can have. To help reduce this risk, the researcher will conduct a familiarization session with the participants to ensure for safety, breathing, form, and technique protocols. The researcher will encourage participants to focus on feet placement, landing, and controlled movements because the landing and countermovement is the most important part to plyometric training. Participants who neglect these protocols will be at higher risk for lower extremity injuries.

Participant Duties:

The participants will be asked to maintain the current exercise programs they are currently participating in, avoid plyometric training on all other days that are not for the intervention, and participants will be required to attend 13 of the 16 training sessions for proper evaluation. Participants will also be required to not exercise two hours before the first and last testing periods to ensure accuracy of body fat calipers. Water hydration is acceptable and encouraged before every session. Participants will be asked to not perform any exercise before all 18 sessions to ensure the quality and accuracy of the study. Participants that fail to attend all required sessions and testing days will be excluded from the study.

Contact information for researchers:

Medical Health Contact Information:

100 N. University Drive

Edmond, OK 73134

Wellness Center, Room 105

(405)-974-3161

UCO IRB Contact:

Compliance Coordinator: Ms. Pam Lumen

Nigh University Center 341, Box 132

(405)-974-5497 or (405)-974-5479

irb@uco.edu

Explanation of confidentiality and privacy:

All participants' information (name, height, weight, body fat percentage, age, gender, hang time, and vertical jump height) will be kept confidential and private from all outside sources and other participants in the study. All the consent forms and a master code sheet with special codes for participant's names will be kept in a safe at the researcher's house. The master sheet will be terminated via shredder after the study is complete for privacy and confidentiality purposes. Informed Consent Forms will be kept on file in the locked safe for three years due to the required federal regulations of the Office of Research Regulatory Affairs.

Assurance of voluntary participation:

The participants are strictly volunteering for the plyometric training intervention. Participants recruited and selected have the complete right to not choose to participate or can also leave the study at any time in which they desire to. There will be no penalty if the participant decides to leave the study.

AFFIRMATION BY RESEARCH SUBJECT

I hereby voluntarily agree to participate in the above listed research project and further understand the above listed explanations and descriptions of the research project. I also understand that there is no penalty for refusal to participate, and that I am free to withdraw my consent and participation in this project at any time without penalty. I acknowledge that I am at least 18 years old. I have read and fully understand this Informed Consent Form. I sign it freely and voluntarily. I acknowledge that a copy of this Informed Consent Form has been given to me to keep.

Research Subject's Name: Landon Paul Jackson

Signature: __________________________________ Date: ________________

Appendix B – Permission to Recruit

Landon Jackson <landon.jackson@teamexos.com>

Jan 24, 2019, 1:37 PM

To James Campbell

Hey James, how are you?

I am emailing you in regards to be granted with your permission to recruit and perform data collecting at your fitness center, Mercy Fitness Center Edmond I-35 on 2017 W I-35 Frontage Rd Edmond, OK 73013. Thank you for your time and the opportunity to use your facility to conduct my graduate thesis project.

Have a good day,

Landon Jackson

James Campbell <james.campbell@teamexos.com>

Jan 24, 2019, 3:13 PM

To me

Landon,

Thank you for your interest in our facility at Mercy Fitness Center Edmond I-35. I would like to accept your request to use our facility for your study. Let's set up a meeting to touch base on when you will be performing this project so we can create a good game plan to get you on the right path.

Thank you,

James Campbell

Appendix C– Recruitment Flyer

Participate in a Research Study

Comparing the Effects on Vertical Jump Height During an Aquatic and Land Plyometric Training Intervention

Qualifications

- Ages 18-40
- Free of lower body injuries for the past year (hip, knee, ankle, etc.).
- No limitations that prevent you from exercising.
- Participation in resistance exercise training at least twice a week for the past 12 months

What is Expected

- 10 weeks of research (8 weeks performing plyometric exercise).
- Sessions will be 2 days/week for approximately 1 hour.
- Participants will be randomly selected into land or aquatic training.
- Participant's head may go underwater during training.

Benefits of participating

- Complimentary dual-energy X-ray absorptiometry (DEXA) scan!
- Opportunity to improve: power, which increases vertical jump height, horizontal jumping length, strength, agility, speed, coordination, and also improve body composition!
- Work with a certified personal trainer!
- Learn new/alternative types of exercises for the future!
- Be a part of a research study!

This project has been approved by the University of Central Institutional Review Board (#2019-150).

Contact: Landon Jackson
580.399.2262 or ljackson29@uco.edu

Mercy Fitness Center EXOS

UCO