THE IMPACT OF AQUATIC BASED PLYOMETRIC

TRAINING ON JUMP PERFORMANCE:

A CRITICAL REVIEW

By

PRYSE M. MULLENAX

Bachelor of Science in Health Education and Promotion

Oklahoma State University

Stillwater, OK

2018

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
July, 2020

THE IMPACT OF AQUATIC BASED PLYOMETRIC

TRAINING ON JUMP PERFORMANCE:

A CRITICAL REVIEW

Thesis Approved:

Dr. Jay Dawes

Thesis Adviser

Dr. Doug Smith

Dr. Michael Trevino

Name: PRYSE MARSHALL MULLENAX

Date of Degree: JULY, 2020

Title of Study: THE IMPACT OF AQUATIC BASED PLYOMETRIC TRAINING ON JUMP PERFORMANCE: A CRITICAL REVIEW

Major Field: HEALTH AND HUMAN PERFORMANCE

Abstract: There is evidence to suggest that aquatic plyometric training (APT) is a safer and effective alternative to traditional land-based plyometric training (LPT) when training to increase jump performance. The aims of this review were to critically examine the current literature investigating the effects of land- vs. aquatic-plyometric training on jump performance in athletes. The author searched key terms in five databases to complete a search of the current literature. Available articles were screened for inclusion and exclusion criteria to decide which studies would be deemed eligible for review. Outcome measure that were used in these studies to assess lower extremity power and jump performance included drop jumps, broad jumps, sergeant jumps, repeated countermovement jumps, and vertical jumps. Results from all, but one of the studies included in this critical review showed significant improvements in athletes' jump performance after LPT and APT interventions. Both LPT and APT groups experienced similar increases in jump performance and lower extremity explosive strength, pre- to post-test, in the majority of the studies examined in this review. In conclusion, LPT and APT may have the ability to increase athletes' lower extremity explosive strength and jump performance. This increase in lower extremity explosive strength may improve overall athletic performance. Observations from this review may be used by strength coaches and athletes alike to weigh the pros and cons of both forms of plyometric training.

TABLE OF CONTENTS

Chapter Page

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

STATEMENT OF THE PROBLEM

Plyometric training (PT) involves performing drills that include different types of hops, jumps, and explosive movements that have the potential to develop power in the lower extremities (Miller, Berry, Bullard, & Gilders, 2002). These types of drills are often characterized by starting stopping, and changing directions in an explosive manner (Miller, Herniman, Ricard, Cheatham, & Michael, 2006). Some examples of plyometric drills include: side-to-side ankle hops, standing jump-and-reach, front cone hops, and double-leg hops (Miller, Cheatham, Porter, Ricard, & Hennigar, 2007). This type of training is used by coaches and performed by athletes to improve vertical jumping ability, speed, strength, and power (Patel, 2014).

While PT is considered an effective training modality for improving lower-body power, it is not without risk. Performing lower body plyometrics presents a risk of injury to the feet, ankles, shins, knees, hips, and lower back (Allerheiligin, & Rogers, 1995). According to Miller, Berry, Gilder, & Bullard (2001), the landing phase of a plyometric drill presents the most significant risk of injury because the amount of force delivered to the musculoskeletal system is increased. The high intensities and volume associated with PT also increase risk of injury (Arazi, Coetzee, & Asadi, 2012).

Performing plyometrics on a hard surface does little to reduce the impact forces associated with this type of training (Allerheiligen, & Rogers, 1995), and because of this, aquatic-based PT has increased in popularity.

The use of aquatic plyometric training (APT) may provide a safer alternative to traditional jump training on land due to the buoyant properties of water (Donoghue, Shimojo, & Takagi, 2011; Miller et al., 2001; Stemm & Jacobson, 2007). These properties reduce the impact forces on the musculoskeletal system during the landing phase, which may aid in the reduction of potential injury (Miller et al., 2001). Despite its increase in popularity, very little studies that have examined the effects of APT on vertical jump performance of athletes. A number of studies have compared an APT to a land plyometric training (LPT) group (Donoghue et al., 2011; Miller et al., 2007; Stemm & Jacobson, 2007), but to date only eight studies have compared these two types of PT using participants that are involved in high school, collegiate, or professional sports.

PURPOSE

The literature suggests that LPT has the ability to increase vertical jump performance (Markovic, 2007). The literature also suggests that APT has the ability to increase vertical jump performance (Arazi et al., 2012; Stemm & Jacobson, 2007). The results from the majority of studies have shown increases in vertical jump performance as a result of both of these types of training (APT and LPT), but there have also been studies that produced no improvements in vertical jump performance as a result of these two types of plyometric training (Miller et al., 2002; Miller et al, 2007; Ploeg, Miller, Holcomb, O'Donoghue, & Berry, 2010). Low sample size and the use of untrained individuals may have influenced the results of many previous studies examining the effectiveness of plyometric training. On this basis, the purpose of this review was to critically examine the literature investigating the effect of LPT vs. APT on athletes' vertical jump performance and to synthesize the findings. A three-stage search strategy was adopted from (Joseph, Wiley, Orr, Schram, & Dawes, 2018), which first examined potential studies to be included in the final review. A total of 202 studies were screened for inclusion and exclusion criteria and only eight were selected to be included in the final systematic review.

RESEARCH QUESTIONS

1. Does LPT significantly improve athletes' vertical jump performance?
2. Does APT significantly improve athletes' vertical jump performance?
3. Does LPT and APT produce similar increases in athletes' vertical jump performance?
4. Does LPT produce greater improvements in athletes' vertical jump performance than APT?

HYPOTHESIS

Null hypothesis:

1. LPT does significantly improve athletes' vertical jump performance.
2. APT does significantly improve athletes' vertical jump performance.
3. LPT and APT do produce similar increases in athletes' vertical jump performance.

4. LPT does not produce greater improvements in athletes' vertical jump performance than APT.

Alternative hypothesis:

1. LPT does not significantly improve athletes' vertical jump performance.
2. APT does not significantly improve athletes' vertical jump performance.
3. LPT and APT do not produce similar increases in athletes' vertical jump performance.
4. LPT does produce greater improvements in athletes' vertical jump performance than APT.

SIGNIFICANCE OF STUDY

Many coaches and athletes use plyometric training because this type of training has the potential to increase lower body strength and power, and can also improve vertical jump performance (Patel, 2014). Many studies have compared LPT and APT training, but have done so using untrained or moderately trained participants. Improvements in vertical jump performance from these participants may have been a result of neurological adaptations and not actual strength gains. This would limit the application of the results of these studies to athletes because athletes are normally highly trained and improvements in vertical jump performance after a lengthy training regimen would likely be the result of actual strength increases and not just neural adaptations. On this basis, critically reviewing studies that compare the effect of LPT vs. APT using athletes as participants will create a better understanding on the impact of these two types of training on athletes vertical jump performance. This may help coaches and athletes consider the pros and cons of these two types of plyometric training.

CHAPTER II

REVIEW OF LITERATURE

INTRODUCTION

The purpose of this review is to determine if LPT and APT produce similar increases in athletes' jump performance and lower extremity explosive power. This chapter will examine important areas of interest such as vertical jump, PT, LPT, APT, APT vs. LPT, and water level.

VERTICAL JUMP

Vertical jump ability is a critical component to the success of an athlete, and often times separates advanced athletes from novices (Baker, 1996; Bobbert, Mackay, Schinkelshoek, Huijing, & Van Ingen Schenau, 1986; Markovic, 2007). When a rapid stretch-shorten cycle precedes a vertical jump, it is then defined as a countermovement jump (CMJ), as opposed to a squat jump (SJ) that does not use a pre-stretch before a vertical jump (Baker, 1996). A CMJ may be more effective than a SJ at increasing vertical jump height (Bobbert, Gerritsen, Litjens, & Van Soest, 1996; Komi, & Bosco, 1978). During a CMJ, the stretch-shortening cycle (SSC) activates and stores energy during the eccentric muscle contraction and later utilizes this stored energy when the muscle acts concentrically (Bobbert et al., 1996; Bosco, Tihanyi, Komi, Fekete, & Apor, 1982). The stored elastic energy that is utilized during the concentric muscle contraction may produce greater work in a CMJ, than work produced in a SJ (Asmussen & Bonde-Peterson, 1974; Bobbert et al., 1996; Komi et al., 1978).

A depth jump (DJ) is another type of plyometric exercise that shortens the knee, hip, and ankle extensors immediately following a rapid and forceful stretch (Holcomb, Lander, Rutland, & Wilson, 1996). When performing a DJ, the individual drops from an elevated surface (usually a box) and, upon landing, leaps vertically as rapidly as possible (Holcomb et al., 1996; Komi et al., 1978). Results from previous literature show that DJs may be more effective at improving vertical jump performance variables than CMJs (Bobbert, Hiujing, & Van Ingen Schenau, 1987; Bobbert et al., 1986; Bosco & Komi, 1979). Results from Bobbert et al. (1987) suggest that the mechanical output from the ankle and knee joints increased during the DJs more than the CMJs. However, results from Gehri, Ricard, Kleiner, and Kirkendall (1998) suggest that DJs and CMJs are equally effective at improving vertical jump ability.

PLYOMETRIC TRAINING

PT is a type of physical conditioning that has gained popularity in athletics and throughout research over the past three decades (Jurado-Lavanant et al., 2018). Greater attention was given to this form of training at the start of the 1970s after Eastern European countries accredited their success in power-dependent events in the Olympics to their participation in PT prior to the games (Ploeg et al., 2010; Stemm & Jacobson, 2007). PT is defined by a rapid eccentric muscle contraction, which stores elastic energy followed by an amortization phase, and then a rapid concentric muscle contraction in which this stored elastic energy is released producing force (Bosco et al., 1982; Donoghue et al., 2011; Komi & Bosco, 1978; Marcovic, 2007; Miller et al., 2002; Miller et al., 2007; Stemm & Jacobson, 2007). Training the neuromuscular apparatus, to make a rapid transition from an eccentric to a concentric action, may reduce the amortization and thrust phase of a vertical jump, ultimately increasing power production (Holcomb et al., 1996).

APT is an alternative form of jump training that is aimed at reducing the stress placed upon the musculoskeletal system and joints. Moreover, it has been reported that APT also has the potential to reduce the delayed onset of muscle soreness (DOMS), and injury due to the buoyancy of water acting in the opposite way of gravity on the body (Miller et al., 2002; Miller et al., 2007; Prins, & Cutner, 1999, Robinson et al., 2004; Stemm & Jacobson, 2007). APT is performed with a lower load than LPT because of the buoyant properties of water (Miller, et al., 2002). This allows for a faster transition from the eccentric phase to the concentric phase because the amortization phase takes less time (Miller et al., 2002). LPT is performed with a heavier load because there is no water acting in the opposite way of gravity on the body (Miller et al., 2002). This heavier load slows the transition from an eccentric muscle contraction to a concentric muscle contraction by prolonging the amortization phase (Miller et al., 2007).

LAND PLYOMETRIC TRAINING

LPT has the potential to increase muscle strength and power (Bobbert et al., 1996). When performing plyometrics, gravity acts as a force that an athlete uses as energy to store within the body (Adams, O’Shea, O’Shea, & Climstein, 1992). This type of training helps to aid the neuromuscular system transition from an eccentric to concentric muscle contraction (Adams et al., 1992). The SSC of musculotendinous tissue is utilized while performing plyometric exercises (Patel, 2014). This type of training is highly intense, potentially dangerous, and could result in injury if performed incorrectly (Patel, 2014). Despite the risk associated with PT, this type of training may still be safely implemented and may also have the potential to increase speed, strength, power, and also jumping ability (Patel, 2014). However, results from previous literature have shown mixed results pertaining to the effects of PT on vertical jump performance (Markovic, 2007).

Findings from numerous studies depict a significant ($p < .05$) increase in vertical jump performance as a result of PT (Adams et al., 1992; Gehri et al., 1998; Holcomb et al., 1996; Luebbers et al., 2003; Mroczek et al., 2018; Stemm & Jacobson, 2007). Markovic (2007) performed a meta-analytical review, which included 26 different investigations, on "whether or not PT actually improves vertical jump height." Results from this study showed that PT does provide statistically significant improvements to vertical jump height in all four of the standard jumping techniques (SJ, DJ, CMJ, and counter movement jump with the arm swing (CMJA) (Markovic, 2007). Other studies suggest that PT results in no significant improvements in vertical jump performance (Markovic, 2007; Ploeg et al., 2010). Pleog et al. (2010) compared the effect of high-volume aquatic PT on vertical jump performance. Results from this study produced no significant increases in vertical jump height, and the LPT group's vertical jump actually slightly decreased (Ploeg et al., 2010).

AQUATIC PLYOMETRIC TRAINING

Compared to LPT, APT is an alternative form of jump training that may reduce the amount of impact forces placed upon the muscular skeletal system and joints of the human body, which has the potential to decrease DOMS and injury (Miller et al., 2002; Miller et al., 2007; Robinson et al., 2004; Stemm & Jacobson, 2007). Training in an aquatic setting may also be more enjoyable, and offer something new that gives participants a break from the repetitiveness of training on land (Miller et al, 2001). To fully understand how APT reduces impact force during the landing phase, it is important to note how water affects the training environment. The buoyancy of water acts in the opposite way of gravity on the body, while the water viscosity provides resistance when moving through water (Miller et al., 2002; Miller et al., 2001; Prins et al., 1999). The viscosity of water creates greater resistance than normal during concentric movements while the buoyancy of water, during an aquatic plyometric exercise, reduces the stretch reflex and amount of eccentric loading (Martel et al., 2005). Additional muscle activation is required to overcome this resistance to produce the same movement that would be more easily performed on land (Robinson et al., 2004).

When designing an APT program, with the purpose of increasing performance variables, the same principles used on land are followed: the rules for volume, intensity, frequency, and height of jump (Miller et al., 2001). The weight-bearing load while standing in waist-deep water is approximately 40% of total body weight, while the weight-bearing load while standing in chest-deep water is approximately 60% of total body weight (Becker, 2009; Prins et al., 1999). The deeper the water, the greater increase in resistance to movement, which may also decrease SSC reaction time (Miller et al., 2002; Miller et al., 2001).

AQUATIC VS. LAND PLYOMETRIC TRAINING

Stemm and Jacobson (2007) compared land- and aquatic-based plyometrics on vertical jump performance. No significant difference ($p < .05$) was seen between the aquatic- and land-based groups when comparing the variables measured to assess vertical jump performance, but both of these groups significantly ($p < .05$) outperformed the control group (Stemm & Jacobson, 2007). These findings are supported by Jurado-Lavanant, Fernández-García, Pareja-Blanco, and Alvero-Cruz (2014) who reported that the aquatic- and land-based plyometric groups produced similar increases in vertical jump performance, but no significant difference ($p < .05$) was seen between the two groups.

While some studies have shown similar effects between aquatic and land-based plyometric training, there are also studies that depict a difference between the two groups. Findings from Miller et al. (2002) revealed a significant increase in muscle power pre- to post-test in the APT group ($p < .05$), but there was no significant difference in muscle power pre- to post-test within the land training group. Results from this study are supported by Arazi et al. (2012), who reported a significant increase ($p < .05$) in all of the variables measured pre- to post-test for the aquatic PT group compared to the control group. However, the land PT group only experienced a significantly greater ($p < .05$) pre- to post-test increase in the vertical jump test compared to the control group. While both of these studies reveal greater significant improvements in vertical jump performance in the APT groups, small sample sizes may have limited the ability of the LPT groups to reach significant increases in all of the vertical jump performance variables measured.

WATER LEVEL

Performing PT in an aquatic setting has the potential to decrease injury by limiting the impact placed upon joints and the musculoskeletal system (Miller et al., 2007; Robinson et al., 2004; Stemm & Jacobson, 2007). This reduction of impact forces placed upon the musculoskeletal system and joints of the body is due to the buoyancy and viscosity of water (Miller et al., 2002; Miller et al., 2001; Prins, et al., 1999). The buoyancy of water acts in the opposite way of gravity on the body, while the viscosity of water adds resistance to movements that would be easier performed on land (Prins et al., 1999). Miller et al. (2007) compared the effects of aquatic plyometric training in varying levels of water (chest-deep or waist-deep) on vertical jump performance. Results showed no significant increases in any of the vertical jump performance variables measured between any of the groups. While results from this study did not produce significant results, low sample size may have limited the ability to reach statistical significance.

CHAPTER III

METHODOLOGY

INTRODUCTION

In this chapter the methods and procedures utilized in this thesis will be discussed. This chapter will depict how the search strategy was developed and how each study, gathered from the rapid literature review, was screened for inclusion and exclusion criteria.

DEVELOPING SEARCH STRATEGY

This critical review adopted the search strategy of (Joseph et al., 2018). This search strategy utilized a three-stage approach to identify and obtain studies that could potentially be used in this critical review. To help formulate the search strategy, a rapid literature review was conducted on 25 March 2020 during the first stage of the three-stage approach. When developing key search terms, known research was used and commonly used terms were identified and extracted. The second stage consisted of entering the aforementioned search terms into the following databases: PUBMED, SPORTDiscus, GoogleScholar, EMBASE, and MEDLINE. To meet the individual search strategies within each database, key search terms were modified as required (see Table 1).

To rule out studies that did not include humans the ‘human-only’ filter was applied when available, and was manually applied when the filter option was not available.

Table 1: Databases and search terms

Database	Search Terms
PUBMED (25 March 20)	(“Aquatic Plyometric”) OR (“Water Plyometric”) OR (“Aquatic Jump Training”) AND (“Vertical Jump” OR “Squat Jump” OR “Countermovement Jump”) AND (“Jump Performance” OR “Jump Height” OR “Flight Time” OR “Power” OR “Velocity”)
SPORTDiscus (25 March 20)	(“Aquatic Plyometric”) OR (“Water Plyometric”) OR (“Aquatic Jump Training”) AND (“Vertical Jump” OR “Squat Jump” OR “Countermovement Jump”) AND (“Jump Performance” OR “Jump Height” OR “Flight Time” OR “Power” OR “Velocity”)
GoogleScholar (25 March 20)	(“Aquatic Plyometric”) OR (“Water Plyometric”) OR (“Aquatic Jump Training”) AND (“Vertical Jump” OR “Squat Jump” OR “Countermovement Jump”) AND (“Jump Performance” OR “Jump Height” OR “Flight Time” OR “Power” OR “Velocity”)
EMBASE (25 March 20)	(“Aquatic Plyometric”) OR (“Water Plyometric”) OR (“Aquatic Jump Training”) AND (“Vertical Jump” OR “Squat Jump” OR “Countermovement Jump”) AND (“Jump Performance” OR “Jump Height” OR “Flight Time” OR “Power” OR “Velocity”)
MEDLINE (25 March 20)	(“Aquatic Plyometric”) OR (“Water Plyometric”) OR (“Aquatic Jump Training”) AND (“Vertical Jump” OR “Squat Jump” OR “Countermovement Jump”) AND (“Jump Performance” OR “Jump Height” OR “Flight Time” OR “Power” OR “Velocity”)

INCLUSION AND EXCLUSION CRITERIA

After articles were obtained using key search terms in the listed databases, the duplicates were removed and each article was screened for inclusion and exclusion criteria. This was done by screening the title and abstract of each article and determining if it could potentially be used for review. Criteria for inclusion were as follows: (a) study available in English or can be translated to English; (b) study available in full text; (c) study used human participants only; (d) study involved participants performing PT in water; and (e) study used at least one performance based outcome measure. After the tittle and abstract of each article was screened for inclusion criteria and the articles that did not meet all the inclusion requirements were removed, the remaining articles were screened using criteria for exclusion listed (Table 2).

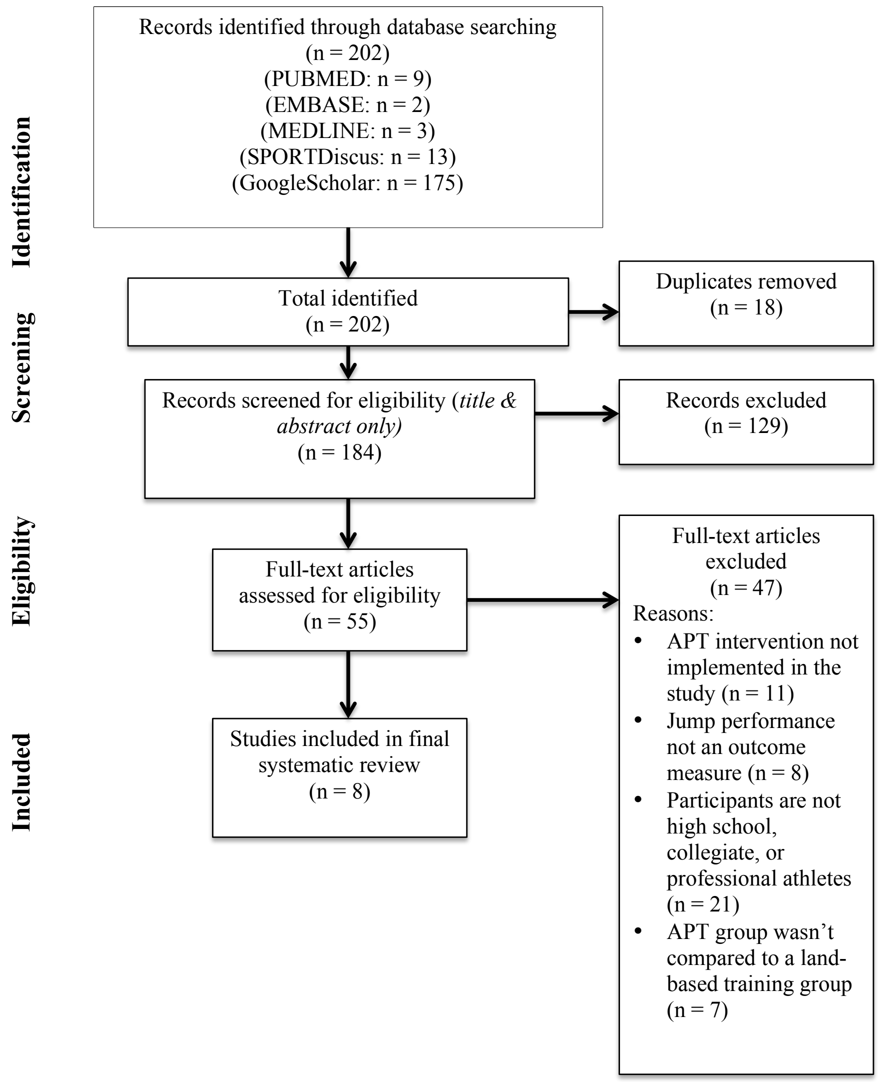
Table 2: Exclusion criteria and examples of excluded studies

Exclusion Criteria	**Example**
Study was not a new investigation	Study was a critical or systematic review
Study examined injuries of participants	Study predicted injury rate of participants by performing vertical jumps on a jump mat
Participants are not high school, collegiate, or professional athletes	Study included participants who were recreationally active college students
Participants were not performing PT in an aquatic environment	Study examined the effect of LPT on jump performance
Study did not measure at least one jump performance based outcome measure	Study examined the effect of APT on speed and agility
APT group wasn't compared to a land-based training group	Study examined the effects of traditional PT on vertical jump performance

STUDY SELECTION AND DEMOGRAPHICS

The critical review process is shown in the PRISMA flow chart (Figure 1), which illustrates how research articles were refined and selected for inclusion in this critical review. Figure 1 also shows the number of articles that were found before screening, and removal of the duplicates that occurred. In all, 202 studies were identified across five databases. Studies from the five databases were pulled together and duplicates were removed. There were a total of 18 articles removed as duplicates. This resulted in a total of 184 articles eligible to be screened for inclusion criteria. After screening for inclusion criteria, 129 articles were removed, leaving 55 full-text articles to be assessed for exclusion criteria. Articles were excluded if an APT intervention was not implemented in the study, jump performance was not an outcome measure, participants were not high school, collegiate or professional athletes, and if an APT group wasn't compared to a land-based training group. After being assessed for exclusion criteria, 47 of the 55 studies eligible were removed, leaving eight studies to be included in the final systematic review.

Figure 1: Systematic Search Strategy



In all, eight studies were deemed eligible for review and were included in the final systematic review. Of these studies, one was conducted in the USA (Coleman, 2011), one in Egypt (Elbattaway & Zaky, 2014), one in Brazil (Fonseca et al., 2017), one in Iran

(Fatahhi et al., 2015), one in India (Datta & Bharti, 2015), one in Turkey (Balvi, 2012), one in Saudi Arabia (Ahmed, Seleem, & Elsayed, 2019), and one in South Africa (Fabricius, 2011). Five of these studies used male only participants (Ahmed et al., 2019; Datta & Bharti, 2015; Fabricius, 2011; Fattahi et al., 2015; Fonseca et al., 2017), two studies used female and male participants (Bavli, 2012; Coleman, 2011), and one study did not specify the gender of the participants (Elbattaway & Zaky, 2014). Two studies examined and tested basketball players (Ahmed et al., 2019; Bavli, 2012), two studies tested volleyball players (Elbattaway & Zaky, 2014; Fattahi et al., 2015), one study tested soccer players (Fonseca et al., 2017), one study tested track and field athletes (Coleman, 2011), and one study tested rugby players (Fabricius, 2011). Two studies implemented a six-week APT program (Coleman, 2011; Fonseca et al., 2017), one study implemented a seven-week APT program (Fabricius, 2011), two studies implemented an eight-week APT program (Ahmed et al., 2019; Fattahi et al., 2015), one study implemented a ten-week APT program (Elbattaway & Zaky, 2014), and two studies implemented a 12-week APT program (Bavli, 2012; Datta & Bharti, 2015).

CRITICAL APPRAISAL AND DATA EXTRACTION

After all 184 studies were subjected to inclusion and exclusion criteria, the remaining studies were critically appraised using the levels of evidence scale adapted from the Oxford Centre for Evidence-Based Medicine (CEBM). This scale can be used to determine the level of evidence of each study, which can help clinicians determine the value of the results reported (Medina, McKeon, & Hertel, 2006). The levels of evidence of this scale ranges from one to five with level one representing the highest quality and level five representing the lowest quality (Medina et al., 2006). Level one consists of systematic reviews of randomized controlled trials (RCTs), Individual RCTs, high-quality prospective or diagnostic studies, and well-designed cost-analysis studies (Medina et al., 2006). Level two consists systematic reviews of cohort studies, well-designed individual cohort studies, and outcome research (Medina et al., 2006). Level three consists of systematic reviews of case-control studies and well-designed individual case-control studies (Medina et al., 2006). Level four consists of case series, poorly-designed cohort studies, and poorly-designed case-control studies (Medina et al., 2006). Level five consists of anecdotal evidence, animal research, bench research, and unpublished clinical observations (Medina et al, 2006).

The CEBM has developed a systematic method for grading to be used in clinical practice that gives a score of quality ranging from A, B, C, D, or I, which shows how well the evidence answers the question of interest (Medina et al., 2006). Level one evidence with consistent results receives a grade of A. A grade of B is given to level two and three with consistent evidence or level one with inconsistent evidence (Medina et al., 2006). A grade of C recommendation is given to studies that show conflicting or level 4 based evidence (Medina et al., 2006). A grade of D or I depicts that the results of the study shows very little evidence to make a recommendation (Medina et al., 2006). This grading system shows how confident clinicians are about the results of each study and how applicable and reproducible they may be (Medina et al., 2006). Once the critical appraisal of the eight studies was completed, key data was extracted and tabled. Information that was extracted from the eight studies included all authors, title of study, year of publication, purpose, design, sample, results, discussion/limitations, and future research aims if available.

CHAPTER IV

RESULTS

INTRODUCTION

In this chapter the eight studies included in the final review will be critically appraised. Results of each of the eight studies, and jump performance test used, will also be discussed.

CRITICAL APPRAISAL OF STUDIES

Six of the studies were given a grade of B (Ahmed et al., 2019; Coleman, 2011; Elbattaway & Zaky, 2014, Fabricius, 2011; Fattahi et al., 2015; Fonseca et al., 2017), which represents a fair level of confidence for making a recommendation. Two of the studies were given a grade of C (Bavli, 2012; Datta & Bharti, 2015), which represents conflicting evidence for recommendation. A grade of B was given to studies that showed level two or three evidence, and if the results of the study were statistically significant or nonsignificant with little variation, which was illustrated by narrow confidence intervals and small standard deviations (Medina et al., 2006).

STUDY CHARACTERISTICS AND FINDINGS

The outcome measurements for jump performance varied across the included studies, with some studies using multiple tests and others using just one test to assess jump performance. Jump performance test used by the eight studies included: drop jump test (Fonseca et al., 2017), broad jump test (Elbattaway & Zaky, 2014; Fabricius, 2011), sergeant jump test (Fabricius, 2011; Fattahi et al., 2015), repeated countermovement jumps test (Fabricius, 2011), and vertical jump test (Ahmed et al., 2019; Bavli, 2012; Coleman, 2011; Datta & Bharti, 2015; Elbattaway & Zaky, 2014). Instruments used to assess jump performance included a jump mat, Vertec vertical jump tester, and a wall and chalk to perform the sergeant vertical jump test. Each of the studies that have been included used one or multiple of the test above to assess jump performance before and after implementation of a 6-12 week aquatic plyometric vs. land plyometric training intervention.

DROP JUMP TEST

One of the included studies measured jump performance in the form of a drop jump test (Fonseca et al., 2017). Fonseca et al. (2017) did this by having the participants depart from a 50-cm high bench with their hands fixed close to the hip region and upon landing on the jump mat, immediately performing a vertical jump. Results from Fonseca et al. (2017) produced significant increases ($p < 0.05$) pre- to post-test in vertical jump height of both the LPT group (40.16cm vs. 46.29cm) and the APT group (36.57cm vs. 45.93cm). Foot contact time significantly decreased from pre- to post-test in the APT group (482.46ms vs. 376.19ms). In the inter-group comparison, a significant decrease was seen ($p < 0.05$) in foot contact time in the APT group (-106.27ms) when compared with the LTP group (-28.69ms) and control group (-4.01ms) in the post-test. Fonseca et al. (2017) concluded that both the LPT and APT group produced significant increase pre- to post-test in vertical jump performance.

BROAD JUMP TEST

Two of the studies included in this review measured jump performance in the form of a broad jump test (Elbattaway & Zaky, 2014; Fabricius, 2011). Participants did this by standing behind the starting line with their feet comfortably apart and then jumping maximally horizontally with a countermovement performed prior to take off (Fabricius, 2011). After landing a measurement is taken from the starting line to the back of the closest heel (Fabricius, 2011). Results from Fabricius (2011) revealed no significant improvements pre- post-test in horizontal explosive performance in either experimental group (LPT and APT). The APT group showed a positive trend in horizontal explosive performance from pre- to post-test by increasing performance by 3.6%. Results from Elbattaway & Zaky (2014) revealed significant improvements in horizontal explosive performance from pre- to post-test in both the aquatic experimental groups (hip- and chest-deep). Results from Elbattaway & Zaky (2014) did not reveal significant improvements in horizontal explosive performance from pre- to post-test in the LPT group.

SERGEANT JUMP TEST

Two of the studies included in this review measured vertical jump performance via a sergeant jump test (Fabricius, 2011; Fattahi et al., 2015). Participants performed this test by standing against a wall with their dominant shoulder and leg (Fabricius, 2011). They then reached as high as they could on the wall and put a mark on the wall at the tip of their middle finger (Fabricius, 2011). After they got their standing reach mark on the wall, they put chalk on the tips of their fingers and jumped as high as possible and smacked the wall at the peak of their jump (Fabricius, 2011). The distance between the chalk mark and the original reach mark is calculated and recorded to the nearest cm (Fabricius, 2011). Fabricius (2011) reported significant improvements pre- to post-test, in sergeant jump performance, in all three groups (APT, LTP, and CON). No statistical differences existed between the three groups, but the APT group showed the greatest improvements with a 7.88% increase in vertical jump performance (Fabricius, 2011). The LPT and CON group followed with increases of 7.06% and 6.69%, respectively (Fabricius, 2011). Results from Fattahi et al. (2015) showed a 28% increase ($p < 0.05$) in vertical performance pre-to post-test in the APT group. The LPT group improved vertical jump performance by 10.5% from pre-to post-test. (Fattahi et al., 2015). Fabricius (2011) concluded that APT has the ability to produce similar and maybe even better improvements in vertical jump performance than LPT. Fattahi et al. (2015) concluded that both APT and LPT have the potential to significantly increase leg power in young male volleyball players.

REPEATED COUNTERMOVEMENT JUMPS TEST

One of the included studies measured jump performance in the form of a repeated countermovement jumps test (Fabricius, 2011). Participants perform this test by attaching a Fitrodyne to their waist and completing a single test of 20- continuous vertical jumps (Fabricius, 2011). A fatigue index calculation was also used to reveal decline in power output during the test expressed as a percentage (Fabricius, 2011). Statistically significant increases pre- to post-test in minimum (1470.5W ± 216.6W vs. 1572W± 259.3W), maximum (1823.4W ± 276.5W vs. 1922.2W ± 315.8W), and average (1646.3W ± 250.6W vs. 1744.2W ± 274.2W) peak power values in the LPT group were discovered. As for peak velocity measurements, the APT group produced no improvements in minimum velocity (1.98 $m.s^{-1}$ ± 0.14 $m.s^{-1}$ vs. 1.97 $m.s^{-1}$± 0.17$m.s^{-1}$) and fatigue index score (21.75% ± 3.63% vs. 22.22% ± 3.47%) (Fabricius, 2011). The LPT group decreased peak velocity fatigue rates from pre- to post-test by 5.98%.

VERTICAL JUMP TEST

Five of the studies included in this review measured jump height and performance in the form of a vertical jump test (Ahmed et al., 2019; Bavli, 2012; Coleman, 2011; Datta & Bharti, 2015; Elbattaway & Zaky, 2014). Ahmed et al. (2019) showed that an eight-week APT program increased vertical jump performance by 18%. This was a statistically greater improvement ($p < .05$) than the 10% increase seen by the LPT program (Ahmed et al., 2019). Similarly, Bavli (2012) discovered significant increases in vertical jump height (cm) pre-to post-test in both the APT group (47.2 ± 5.2 vs. 51.7 ± 5.2) and the LPT group (48 ± 9.3 vs. 52.6 ± 8.8). There were no significant differences between the two experimental groups, but both experimental groups saw significantly greater improvements in vertical jump height than the CON group (43.7 ± 8.2 vs. 45.3 ± 8.8) (Bavli, 2012). Coleman (2011) produced no significant increases in vertical jump performance from pre- to post-test in either of the experimental groups (APT, or LPT). Datta & Bharti (2015) produced significantly greater improvements in vertical jump height in both the land (+0.03 meters) and aquatic training group (+0.05 meters) when compared to the control group (+0 meters). Datta & Bharti (2015) concluded that the APT group significantly increased leg explosive power greater than that of the LPT group and the CON group. Elbattaway and Zaky (2014) compared vertical jump performance of a LPT group, chest-deep APT group, and a hip-deep APT group before and after ten weeks of PT. Results showed significant increases ($p < 0.05$), in vertical jump performance (cm), pre- to post-test in all three group: LPT group (55.13 ± 4.76 vs. 59.75 ± 3.62), chest-deep APT group (54.75 ± 4.92 vs. 67.88 ± 4.05), and hip-deep APT group (49.88 ± 4.45 vs. 59.62 ± 8.09).

CHAPTER V

DISCUSSION

INTRODUCTION

The main objective of this critical review was to pinpoint and critically appraise the methodological quality of studies examining the effects of APT and LPT on athletes' jump performance. Four key areas that will be discussed include: (1) the effect of APT on athletes' jump performance; (2) the effect of LPT on athletes' jump performance; (3) implications of the findings attributed to athletic population based on the level of evidence found in the eight included studies and potential advice to limit these implications; and (4) limitations.

THE EFFECT OF APT ON ATHLETES' JUMP PERFORMANCE

Jump performance was shown to improve, pre- to post-test, across the majority of the included studies when participants were exposed to an APT intervention. Of the eight studies included in this critical review, seven studies showed significant increases in jump performance after participation in an APT intervention (Ahmed et al., 2019; Bavli, 2012; Datta & Bharti, 2015; Fabricius, 2011; Fattahi et al., 2015; Fonseca et al., 2017; Elbattaway & Zaky, 2014). Coleman (2011) was the only study in this critical review that didn't find a significant increase, pre- to post-test, in jump performance after participation in an APT intervention. This study started with 31 participants, but only 26 completed the full length of the study and results' were used. This lower sample size may have limited the statistical power of this study, which may have limited the ability to produce significant results.

Fabricius (2011) found significant increases, pre- to post-test, in the sergeant vertical jump test after participation in an APT intervention. Fabricius (2011) did not find significant increases, pre- to post-test, in the standing broad jump test or the repeated countermovement jump test after participation in an APT intervention. The APT group displayed a positive trend ($p = 0.051$) in the standing broad jump, pre- to post-test, but significance was not reached (Fabricius, 2011). Elbattaway and Zaky (2014) was the only other study, in this critical review, to examine jump performance in the form of a broad jump test. This study found significant improvements, pre- to post-test, in standing broad jump in the both the hip- and chest-deep aquatic plyometric groups. Two studies found that the APT group significantly improved upon vertical jump performance greater than that of the LPT group (Ahmed et al., 2019; Datta & Bharti, 2015). This information should be taken into consideration when planning and implementing a plyometric training program for athletes.

THE EFFECT OF LPT ON ATHLETES' JUMP PERFORMANCE

In the same manner as APT, jump performance was also shown to improve, pre- to post-test, across the majority of the included studies when participants were exposed to an LPT intervention. Seven of the eight included studies showed significant increases, pre- to post-test, in jump performance after participants were exposed to a LPT intervention (Ahmed et al., 2019; Bavli, 2012; Datta & Bharti, 2015; Elbattaway & Zaky, 2014; Fabricius, 2011; Fattahi et al., 2015; Fonseca et al., 2017). Coleman (2011) was the only study that did not find significant increases, pre- to post-test, in jump performance after participants took part in a LPT intervention. Elbattaway and Zaky (2014) saw significant increases, pre- to post-test, in VJ but not broad jump after participants took part in a LPT intervention. This study examined a chest-deep APT group, hip-deep APT group, and a LPT group before and after a ten week training intervention. The LPT group was the only group that did not produce significant increases in broad jump at the end of the ten-week training intervention.

IMPLICATIONS AND RECOMMENDATIONS

Utilizing APT requires access to a pool and maybe even a lifeguard on duty. This coupled with the fact that an athlete must change in and out of aquatic clothing, dry off and change back into street clothes, may limit the amount training that will actually get done in the time that is allotted. Time spent preparing for APT may make LPT a more feasible option for someone who is physically able to endure the type of impact forces that come with this type of training. Although APT may be as effective as LPT, it might not always be the most feasible option of PT. Because of the buoyant properties of water, APT may be utilized by someone who is coming back from a lower extremity injury and wants to start getting back into training, but is not really ready for a full load to be endured by their lower extremities.

LIMITATIONS

Some limitations of this study that are important to note included a potential language bias as a result of English only databases and search terms being used. This language bias may have limited the number of studies eligible to be included in this review. Moreover, this study reviewed the effect of plyometric training on the athletic population, considering this; the general population may not assume the findings from this study. Given that athletes are normally highly trained it can be assumed that significant increases in performance after exposure to a training intervention are not the result of neuromuscular adaptations, but of actual strength increases. Significant increases experienced by untrained individuals after exposure to a training intervention may not be the result of actual strength gains, but of neuromuscular adaptations. Lastly, only two studies (Bavli, 2012; Coleman, 2011) stated that female participants were included. With only two of the eight studies including female participants, this may have limited the generalizability of the observations of this study to male athletes only.

CHAPTER VI

CONCLUSION

In conclusion, this critical review observed that LPT and APT may have the potential to significantly increase jump performance in athletic populations. This would result in an increase in lower extremity explosive power, which may increase overall athletic performance. APT saw significantly greater increases in jump performance than LPT in two of the eight studies reviewed. This is not enough evidence to assume that APT is a more efficient way to improve jump performance than LPT. Overall, the majority of the included studies in this review saw similar increases in jump performance after participation in both LPT and APT interventions. APT could benefit coaches and athletes looking to utilize PT while also reducing impact forces placed upon the musculoskeletal system. Strength coaches and athletes alike may use observations made in this review to weigh the pros and cons of both types of plyometric training.

REFERENCES

Adams, K., O'Shea, J. P., O'Shea, K. L., & Climstein, M. (1992). The effect of six weeks of squat, plyometric and squat-plyometric training on power production. *Journal of Applied Sport Science Research*, *6*, 36-41.

Ahmed, T., Seleem, H. A., & Elsayed, G. (2019). Effects of eight weeks aquatic-non-aquatic training program on aerobic fitness and physical preparation in junior basketball players. *Life Science Journal*, *16*, 111-118.

Allerheiligen, B., & Rogers, R. (1995). Plyometric program design. *Strength and Conditioning Journal*, *17*, 26-31.

Arazi, H., Coetzee, B., & Asadi, A. (2012). Comparative effect of land- and aquatic-based plyometric training on jumping ability and agility of young basketball players. *South African Journal of Research in Sport*, *34*, 1-14.

Asmussen, E., & Bonde-Peterson, F. (1974). Storage of elastic energy in skeletal muscles in man. *Acta Physiologica Scandinavica*, *91*, 385-392.

Baker, D. (1996). Improving vertical jump performance through general, special, and specific strength training: A brief review. *Journal of Strength and Conditioning Research*, *10*, 131-136.

Bavli, O. (2012). Comparison the effect of water plyometrics and land plyometrics on body mass index and biomotorical variables of adolescent basketball players. *International Journal of Sports and Exercise Science*, *4*, 11-14.

Becker, B. E. (2009). Aquatic therapy: Scientific foundations and clinical rehabilitation applications. *American Academy of Physical Medicine and Rehabilitation*, *1*, 859-872.

Bobbert, M. F., Gerritsen, K., Litjens, M., & Van Soest, A. (1996). Why is countermovement jump height greater than squat jump height. *Medicine and Science in Sports and Exercise*, *28*, 1402-1412.

Bobbert, M. F., Huijing, P. A., & Van Ingen Schenau, G. (1987). Drop jumping. I. the influence of jumping technique on the biomechanics of jumping. *Medicine and Science in Sports and Exercise*, *19*, 332-338.

Bobbert, M. F., Mackay, M., Schinkelshoek, D., Huijing, P. A., & van Ingen Schena, G. J. (1986). Biomechanical analysis of drop and countermovement jumps. *European Journal of Applied Physiology*, *54*, 566-573.

Bosco, C., Tihanyi, J., Komi, P. V., Fekete, G., & Apor, P. (1982). Store and recoil of elastic energy in slow and fast types of human skeletal muscles. *Acta Physiologica Scandinavica*, *116*, 343-349.

Coleman, M. M. (2011). The effects of aquatic plyometrics on sprint performance on high school sprinters (Unpublished master's thesis). Sacramento State University, Sacramento, California, America.

Datta, N. K., & Bharti, R. (2015). Effect of aquatic and land plyometric training on selected physical fitness variables in intercollegiate male handball players. *International Journal of Medical, Health, Biomedical, Bioengineering and Pharmaceutical Engineering*, *9*, 449-451.

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

Elbattaway, K. A., & Zaky, W. (2014). The effect of aquatic plyometric training on some physical fitness variables among volleyball players. *Assuit Journal of Sport Science and Arts*, *114*, 390-404.

Fabricius, D. L. (2011). Comparison of aquatic- and land-based plyometric training on power, speed and agility in adolescent rugby union players. Stellenbosch University, Stellenbosch Central, Stellenbosch, South Africa.

Fattahi, A., Kazemini, H., Rezaei, M., Rahimpour, M., Bahmani, M., Nia, S., ... Einanloo, M. (2015). Effect of different plyometric training on biomechanical parameters of junior male volleyball players. *Journal of Scientific Research & Reports*, *4*, 473-479.

Fonseca, R. T., Nunes, R., Castro, J., Lima, V. P., Silva, S. G., Dantas, H. M., & Vale, R. (2017). The effect of aquatic and land plyometric training on the vertical jump and delayed onset muscle soreness in Brazilian soccer players. *Human Movement*, *18*, 63-70.

Gehri, D. J., Ricard, M. D., Kleienr, D. M., & Kirkendall, D. T. (1998). A comparison of plyometric training techniques for improving vertical jump ability and energy production. *Journal of Strength and Conditioning Research*, *12*, 85-89.

Holcomb, W. R., Lander, J. E., Rutland, R. M., & Wilson, G. D. (1996). A biomechanical analysis of vertical jump and three modified plyometric depth jumps. *Journal of Strength and Conditioning Research*, *10*, 83-88.

Joseph, A., Wiley, A., Orr, R., Schram, B., & Dawes, J. J. (2018). The impact of load carriage on measures of power and agility in tactical occupations: A critical review. *International Journal of Environmental Research and Public Health*, *15*, 1-16.

Jurado-Lavanant, A., Alvero-Cruz, J. R., Pareja-Blanco, F., Melero-Romero, C., Rodríguez-Rosell, D., & Fernández-García, J. C. (2018). The effects of aquatic plyometric training on repeated jumps, drop jumps and muscle damage. *International Journal of Sports Medicine*, *39*, 764-772.

Jurado-Lavanant, A., Fernández-García, J. C., Pareja-Blanco, F., & Alvero-Cruz, J. R. (2014). Effects of land vs. aquatic plyometric training on vertical jump. *International Journal of Medicine and Science of Physical Activity and Sport*, *17*, 73-84.

Komi, P. V., & Bosco, C. (1978). Utilization of stored elastic energy in leg extensor muscles by men and women. *Medicine and Science in Sports*, *10*, 261-265.

Luebbers, P. E., Potteiger, J. A., Hulver, M. W., Thyfault, J. P., Carper, M. J., & Lockwood, R. H. (2003). Effects of plyometric training and recovery on vertical jump performance and anaerobic power. *Journal of Strength and Conditioning Research*, *17*, 704-709.

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

Medina, J. M., McKeon, P. O., & Hertel, J. (2006). *Rating the levels of evidence in sports-medicine research* (M. G. Dolan, Ed.). (pp 38-41). Human Kinetics.

Marcovic, G. (2007). Does plyometric training improve vertical jump height? A meta-analytical review. *British Journal of Sports Medicine*, *41*, 349-355.

Miller, M. G., Berry, D. C., Bullard, S., & Gilders, R. (2002). Comparison of land-based and aquatic-based plyometric programs during an 8-week training period. *Journal of Sports Rehabilitation*, *11*, 268-283.

Miller, M. G., Berry, D. C., Gilder, R., & Bullard, S. (2001). Recommendations for implementing an aquatic plyometric program. *National Strength & Conditioning Association*, *23*, 28-35.

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*, 145-155.

Miller, M. G., Herniman, J. J., Ricard, M. D., Cheatham, C. C., & Michael T.J. (2006). The effect of a 6-week plyometric training program on agility. *Journal of Sports Science and Medicines*, *5*, 459-465.

Mroczek, D., Mackala, K., Kawczynski, A., Superlak, E., Chmura, P., Seweryniak, T., & Chmura, J. (2017). Effects of volleyball plyometric intervention program on vertical jumping ability in male volleyball players. *The Journal of Sports Medicine and Physical Therapy*, *58*, 1611-1617.

Patel, N. N. (2014). Plyometric training: A review article. *Journal of Current Research Review*, *6*, 33-37.

Ploeg, A. H., Miller, M. G., Holcomb, W. R., O'Donoghue, J., Berry, D., & Dibbet, T. J. (2010). The effect of high volume aquatic plyometric training on vertical jump, muscle power, and torque. *International Journal of Aquatic Research & Education*, *4*, 39-48.

Prins, J., & Cutner, D. (1999). Aquatic therapy in the rehabilitation of athletic injuries. *Clinics in Sports Medicine*, *18*, 447-461.

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. *Journal of Strength & Conditioning Association*, *18*, 84-91.

Stemm, J. D., & Jacobson, B. H. (2007). Comparison of land- and aquatic-based plyometric training on vertical jump performance. *Journal of Strength & Conditioning Research*, *21*, 568-571.

VITA

Pryse Marshall Mullenax

Candidate for the Degree of

Master of Science

Thesis: THE IMPACT OF AQUATIC BASED PLYOMETRIC TRAINING ON JUMP PERFORMANCE: A CRITICAL REVIEW

Major Field: Health and Human Performance

Biographical:

Education:

Completed the requirements for the Master of Science in Applied Exercise Science at Oklahoma State University, Stillwater, Oklahoma in July, 2020.

Completed the requirements for the Bachelor of Science in Health and Human Performance at Oklahoma State University, Stillwater, Oklahoma in 2018.

Experience:

Graduate Research Assistant at Oklahoma State University

400 hour internship at Titan Sports and Performance in Tulsa, OK

American Heart Association First Aid and CPR/AED Basic Life Support Provider

Professional Memberships:

Member of the Honor Society of Phi Kappa Phi