THE EFFECTS OF AQUATIC PLYOMETRICS ON SPRINT PERFORMANCE ON HIGH SCHOOL SPRINTERS

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A Thesis

by

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Department of Kinesiology

Abstract

of

THE EFFECTS OF AQUATIC PLYOMETRICS ON SPRINT PERFORMANCE IN HIGH SCHOOL SPRINTERS

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Introduction

Plyometrics is known to enhance explosive performance in power, vertical jump and sprinting speed however, an increase in injury is prevalent. Aquatic plyometrics elicits identical improvements to land based plyometrics with a reduction of muscle soreness.

Few studies exist that examine the effect of aquatic plyometric training. Only three focus on adolescent athletes. With the majority of plyometric research studies focusing primarily on adults and even less on adolescents in aquatic plyometrics the purpose of the current study emerged.

Methods

Thirty-one subjects were stratified randomly to the two training groups; land based plyometrics and aquatic plyometrics. The subjects were equally placed within the two groups. Each subject performed a vertical jump height test, 20m sprint, 10 meter block start and reported muscle soreness via a Likert type scale. All of variables were measured at the same time of day at Monterey Trail High School for each testing period.

Results

Muscle soreness from the pre, mid, and post muscle soreness test showed that no significant difference existed between the land and the aquatic groups *F* (1, 24) = 2.349, = .138, partial η^2 .089. Vertical jump heights were comparable between the aquatic groups pre (*M* = 24.5, *SD* = 4.06) and post test (*M* = 24.73, *SD* = 3.9) to the land based groups pre (*M* = 23.23, *SD* = 5.09) and post test measurements (*M* = 23.46, *SD* = 5.32), *t* (25) = -2.90, *p* = .008 (two tailed). The results from the pre 10 meter block showed that no significant difference exists between the aquatic and land group *F*(1,24) = .947, p = .340, partial η^2 .038 on the pre. The results showed that the aquatic and land based plyometric groups were significantly different on the post block scores *F*(1,24) = 5.538, p <.05, partial η^2 .990. The results from the pre 20 meter sprints showed no difference between the two groups, land and aquatic *F*(1, 24) = 3.056, p = .093 partial η^2 .113.

Conclusion

The results of the present study demonstrated that after 6 weeks of plyometric training the response found in aquatic and land based training had similar values in vertical jump, 20 meter sprint and muscle soreness with an exception on the post test scores for the 10 meter block sprint. There were no differences between the two groups on three of the four variables, indicating that both forms of training were effective.

________________________, Committee Chair
Roberto Quintana, Ph.D.

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Date

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Chapter 1

INTRODUCTION

Plyometric training is the most common method for enhancing performance in explosive, high velocity and high power exercises (Bompa, 1996). Plyometric training increases strength, power and velocity through rapid contraction and the stretch-shortening cycle, where eccentric contraction is followed rapidly by a concentric contraction (Chu, 1992). During the eccentric phase, also referred to as the loading phase, the motor unit recruitment in the muscle is increased by the force of the muscle that is stretched. Once the muscle is stretched to its limit, it then contracts (concentric contraction) allowing all of the force generated to be used by the body in the form of explosive movement. The body is therefore able to produce a greater amount of force to improve an individual's performance in high power and high velocity exercises.

Plyometrics is utilized by many populations. It brings forth numerous improvements in high velocity and power based sports in adults and in adolescents. In adults, plyometric training improves sprinting speed, vertical jump height, muscular hypertrophy and isokinetic strength (Campo, Vaeyens, Phillipaerts, Redondo, Benito & Cuadrado, 2009; Lundin & Berg, 1991; Schulte-Edelmann, Davies, Kernozek, & Grerberding, 2005; Toumi, Best, Martin, Guyer & Poumarat, 2004). In adolescents, plyometrics improves vertical jump height, sprinting speed, cycling speed and hypertrophy (Dean, Nishaihara, Romer, Murphy, & Mannix, 1998; Diallo, Duche & Praagh, 2001; Faigenbaum, McFarland, Keiper, Telvin, Ratamess, Kang & Hoffman, 2007; Kotzamanidis, 2006; Martel, Harmer, Logan & Parker, 2005; Santos & Janetria, 2008; Sova, 2000; Thomas, French & Hayes, 2009).

Although plyometrics is known to enhance explosive performance in power, vertical jump and sprinting speed, an increase in injury is prevalent. With it eccentric forces, the amount of force placed on the musculoskeletal system increases the risk of injury and in some cases intensifies the level of muscle soreness (Martel et al., 2005; Miller, Berry, Bullard & Gilders, 2002; Miller, Cheatham, Porter, Ricard, Hennigar & Berry, 2007; Robinson, Devor, Merrick & Buckworth, 2004; Stemm & Jacobson, 2007; Triplett, Colado, Benavent, Alakhadar, Madera, Gonzalez & Tella, 2009).

The most common form of plyometrics, known as land plyometrics, requires constant jumping and landing which exerts a large amount of force on the lower body (Stemm & Jacobson, 2007). This application of force creates muscle soreness and muscle damage. The muscle damage occurring in land based plyometric training most likely contributed to the development of aquatic plyometrics. Aquatic plyometrics is a form of plyometrics that lessens the impact of muscle soreness and damage (Miller et al., 2002; Miller et al., 2007; Robinson et al., 2004).

Aquatic plyometrics is land based plyometric training that is performed in the water. The energy produced is identical to land based plyometric training. Since aquatic plyometrics are conducted in water, the training effect is maintained while muscle soreness and muscle stress is reduced (Miller et al., 2002; Miller et al., 2007; Robison et al., 2004). Aquatic plyometrics has been proposed to reduce the amount of eccentric forces on the body because of the buoyancy of the water (Martel et al., 2005; Miller et al., 2002; Robinson et al., 2004).

Few studies exist that examine the effect of aquatic plyometric training. Of those in existence only three focus on adolescent athletes (Bishop, Smith, Smith, M. & Rigby, 2009; Martel et al., 2005; Triplett et al., 2009). With the majority of plyometric research studies focusing primarily on adults and even less on adolescents in aquatic plyometrics the purpose of the current study emerged. The present study centered on adolescents and examined both land and aquatic plyometrics on track and field athletes during the outdoor season.

Statement of Purpose

The purpose of this study was to determine whether land based or aquatic plyometric exercise training had an effect on vertical jump height, velocity, initial sprint start and muscle soreness in adolescent high school track and field athletes during their outdoor season.

Significance of Thesis

The present study will present data on plyometrics involving adolescents, a group rarely examined in this research area. It will augment the current body of knowledge regarding adolescent student athletes during their competition season. The finding of this study could provide insight into whether or not plyometric training should be utilized during the completion season or within the pre-season where it is primarily practiced. Additionally, it will add to the current research in adolescent plyometrics that examines the underlying induced training adaptations within the muscle that occurs in plyometric training.

Definition of Terms

Peak power: The maximal amount of power that is exerted during a plyometric countermovement jump.

Muscle soreness: The degree of soreness found within a muscle limb.

Peak velocity: The highest speed (m/s or %/s) attained during a 20m sprint.

Experienced athletes: Anyone that has one year or more of plyometric training.

Creatine Kinase: An enzyme that phosphoralize creatine which aid in supplying energy to the muscle and nerve cells.

Vertical Jump: The highest measurement of one’s center of gravity in the vertical plane by elevating the body in an upward motion.

Hypertrophy: Remodeling protein within the muscle by overloading the muscle which therefore increases muscular size.

Limitations

1. Subjects performed maximally on pre and post-test days.
2. Results found within the study can be generalized to a similar population.
3. The sample size of the study is large enough to bring forth quantitative results.

Delimitations

1. The subjects were high school athletes.

2. The research conducted on comparing the two conditions has primarily been conducted on active college aged adults.
3. The athletes participate in a year around training program.
4. This study was conducted during competitive season.
5. The time allocated with these athletes was limited to 2 ½ hours a day

Assumptions

1. All of the subjects exerted maximally during the training sessions.
2. All of the subjects follow the training program adhered to.
3. All subjects reported muscle soreness honestly and truthfully.
4. All subjects will perform to their best ability on performance tests.
5. All of the subjects did not alter their outside physical activities routine.

Hypotheses

1. There was no significant difference between the aquatic group and land based plyometric group on the measurement of peak power in the vertical jump.
2. There was no significant difference between the aquatic group and land based plyometric group on peak velocity.
3. There was no significant difference between the aquatic group and land based plyometric group on the measure of speed in the 10 meter block start.
4. There was no significant difference between the aquatic group and land based plyometric group on the onset of muscle soreness.

Chapter 2

REVIEW OF LITERATURE

There is currently not a consensus on whether aquatic plyometrics are more effective than land plyometrics in adolescent athletes. However, one study that has examined the effect of plyometrics on land vs. aquatics plyometrics does exist. The study was conducted on vertical jump in adolescent volleyball players. There are only nine studies that have examined land plyometrics on adolescents let alone athletes. The purpose of this review of literature was to introduce and discuss the current knowledge within this area while showing the gaps and inconsistency in literature on adolescents and plyometrics. This chapter examined the effects of power, velocity, and muscle soreness/injury on athletic performance in plyometric training as well as aquatic plyometric training.

The review of literature was organized in two identical sections on land plyometrics and aquatic plyometrics with a background of terms, the benefits, and drawbacks. This is followed by the types of exercises, the benefits of exercises, types of training plans, percent of improvements, the mechanisms of improvements; velocity muscle contraction, power muscle contraction, strength muscle contraction, and muscle soreness/injury.

Review of Plyometrics

Plyometric training is the most common method in enhancing performance explosive, high velocity power exercises (Bompa, 1996). It has been shown to enhance strength, power, and velocity through its rapid contraction through the stretch-shortening cycle, where eccentric contraction is then followed rapidly by a concentric contraction (Chu, 1992). During the eccentric “loading” phase the involuntary motor unit recruitment increases and increases the force that is generated in the concentric contraction phase. The body is therefore able to release a greater amount of force during exercise. The body’s ability to produce a greater amount of force can enhance an individual’s performance in high power and high velocity activities.

Plyometric training provides an individual with numerous benefits. Wilk et al., (1993) found that plyometric training may attribute to neurological adaptations in preventing knee injuries in active adults. Chimera et al., (2004) found similar results in Division One athletes in regards to muscle activation. Myer et, at., (2006) conducted a study on high school athletes and reported that when plyometrics were accompanied with stabilization there was an increase in the control of the dynamic lower extremity valgus which could cause a reduction in lower extremity “ACL” injuries. Along with the reduction in lower extremity injuries, plyometrics has been shown to improve an individual’s power, vertical jump, and speed (Campo et al., 2009; Chu, 1992; Lundin & Berg, 1991Schultle-Edelmann et al., 2005; Toumi et al., 2004).

Although plyometrics has been shown to enhance an individual’s performance in power, vertical jump and speed it has been shown to increase injury rate. Plyometric training requires rapid and explosive exercises potential for injury. The high eccentric loading followed by the landing phase places extremely high loads on the musculoskeletal system and produces large amounts of muscle soreness and increases the risk of lower extremity injury. (Martel et al., 2005; Miller et al., 2002; Miller, et al., 2007; Robinson et al., 2004; Stemm & Jacobson, 2007; Triplett et al., 2009).

Types of Exercises

There are more than 90 different plyometric exercises that are utilized in training. All consists of a jumping or hoping component (Bompa, 1996; Chu, 1992). With more than 90 different exercises there are six lower extremity classifications. They are 1) jumps in place; 2) jumps standing; 3) multi hops and jumps; 4) bounding; 5) box drills and 6) depth jumps. Jumps allow individuals to control their foot placement while increasing strength development and explosiveness. Jumping enhances speed and strength (Bompa, 1996). Bounding allow the individuals to perfect their feet in the landing phase as well as arm action movement. Bounding enhances ground contact and speed (Bompa, 1996). Hops develop power in the legs while absorbing the shock on the surface. Hops enhance leg power and rapid take off (Bompa, 1996). Drills allow individuals to perfect the technical skills of the exercises. Drills enhance the precision of the exercise performed (Bompa, 1996).

Types of Training Plans

Plyometric training programs can be characterize by intensity, volume, frequency and recovery. This is very similar to the FITT principle (frequency, intensity, type and time). The four variables used in plyometrics are: 1) intensity of the exercise based on the level of the individual’s conditioning; 2) volume of work performed based on the number of foot contacts; 3) frequency which includes the number of sets and sessions done per week; and 4) ample recovery to allow the athletes to maintain and repeat maximal efforts

(Chu, 1992). All plyometrics training plans are built around individualizing the training to the activity and the individual as well as progressively increasing the training load (Bompa, 1996).

Length of Training Plans

There is currently not a consensus on what is the appropriate training length for plyometric training programs to enhance performance. Markovic (2007) meta-analysis examined the effect of plyometric training on vertical jump. In Markovic (2007) study, 26 of 56 articles focusing on plyometrics revealed that studies with duration periods of 6 to 12 weeks and of 2 to 3 sessions a week, the participants all showed improvements in vertical jump performance. The six week studies showed just as much improvements, if not more, than did the 12 week studies. In regards to adolescent athletes, improvements were observed after 4 to 10 weeks of two to three sessions a week (Bishop et al., 2009; Breezo et al., 1988; Dean et al., 1998; Diallo et al., 2001; Santos & Janeira, 2008; Thomas et al., 2009). Rest intervals utilized between each exercise are based on the intensity and the overall impact on the lower body. Two to three minutes are used for low intensity/impact, 3-5 minutes for moderate intensity/impact and 8-10 minutes for maximal intensity/impact (Bompa, 1996).

Percent of Improvement

Plyometrics improve explosiveness, maximum power and jumping ability performance in adolescent. It enhances maximum cycling power (pmax) by 12%. Vertical jump height on average increased by 1.6 cm to 3.4 cm (Dean et at., 1998; Diallo et al., 2001; Martel et al., 2005; Santos & Janiera, 2008; Thomas et al., 2009). Sprint performance times on average decreased by 0.03 to 0.15 in 20 meters and 0.14sec in 30 meters (Dean et al., 1998; Diallo et al., 2001; Kotzamanidis, 2006; Sova, 2000; Thomas et al., 2009). Muscle hypertrophy increased by 9.33% in trained cyclist (Diallo et al., 2001). By implementing plyometric training in adolescent athletes the rate of performance is markedly enhanced.

Mechanisms Underlying Improvement in Muscle Mass

Muscle mass is known as the physical size of the muscle. The greater the mass, the greater the amount of force production an individual can create to employ a powerful explosive movement (Robertson et al. 2004). Muscle mass is the contributor to muscle strength via the number of myosin and actin cross bridges formed. With an increase in muscle mass, the amount of force being created and produced will be greater therefore enhancing one’s power, strength and explosivenes produced in plyometric training. Plyometric training is centered on the amount of force the body can create and produce.

There is currently one research study that examined the effect of muscular strength on performance in adolescent athletes. Behm, Wahl, Button, Power & Anderson (2005) performed an elctromyographic activity test on 30 competitive hockey skaters aged 16 to 25. The study was conducted over a 24 hour period. Behm et al., (2005) found, that the maximum rate of contraction of a one repetition maximum test at maximum speed exceeded the turn phase by 22.1% and the stop phase by 33.7% in the quadriceps. However, there was a greater improvement in the maximum rate of contraction in the maximum speed of the hamstring in the turn phase by 34.8% and 29.2% in the stop phase. Behm et al. (2005) concluded that 25% of skating speed is related to the duration of quadriceps contraction rate.

Mechanisms Underlying Improvement in Velocity Muscle Contraction

Velocity is known as the change of displacement over time. In order for velocity to increase within the muscle, the change in displacement with time most improved. Velocity is associated with explosive movements. Plyometric training allows an individual to improve their explosiveness, velocity and dynamic performance. Since velocity of contraction is maximal during plyometric training.

A study by Thomas, French & Hayes (2009) looked at depth jumps versus countermovement jumps on muscular power and agility in youth soccer player. The six week pre and post-test design found that velocity decreased differently in the 20m and 10m sprints between the two groups. Depth jumps and countermovement jumps decreased (.03 seconds and .02 seconds) in the 20m sprint from pre to post-test. An increase of .02 second occurred in the 10m sprint for the depth jump group from pre to post-test. No differences were found between the sprint times in the 10m sprint for the countermovement jump group from pre-to post-test. Thomas et al. (2009) concluded that sprint distances were not short enough to see greater improvements in the ground reaction force found in sprinting. It was suggested that both of the experimental groups are good plyometric training techniques for improving velocity within youth soccer players.

Kotzamanidis (2006) also studied plyometrics sprinting velocity on a 10m, 20m and 30m sprint in pre-pubertal physical education students using the same design and found similar results. Pre-pubertal physical education students were assessed over 10 weeks. There was a .05 second decrease in 10m with a .11 second decrease in 20meters and .14 second decrease in 30m for the experimental group. The control group decreased in .01 seconds in 10m, increased .04 in 20m and increased .03 seconds in 30m. Kotzamanidis (2006) found that the 10m and 20m brought forth larger decreases in running speeds than did the 30m sprints in the experimental group. Kotzamanidis (2006) hypothesized that, the shorter the running distance with adequate recovery, the greater the impact of running velocity on the distance.

In a study by Diallo, Duche & Praagh (2001) on plyometric training accompanied with reduced training on prepubescent soccer players over 10 weeks, the authors found the opposite results of both Thomas et al. (2009) and Kotzamanidis (2006). Diallo et al. (2001) used the same design as Thomas et al. (2009) and Kotzamanidis (2006) and found that the experimental group increased 20m sprint time by .15 seconds. Diallo et al. (2001) concluded that this was caused by the subjects completing a cycling power max (pmax) test as well.

Robinson, Devor, Merrick & Buckworth (2004) study on the effects of land vs aquatic plyometrics on power, torque, velocity and muscle soreness further supports Diallo et al. (2001) on the increase in velocity. Robinson et al. (2004) found that the land plyometric group increased .38 seconds (5.97 to 6.35) in their 40m sprint time from pre-training to post training.

In a study conducted by Faigenbaum, McFarland, Keiper, Tevlin, Ratamess, Kang & Hoffman (2007), a six week short term plyometric and resistance training in adolescent boys found similar results to Diallo et al. (2001) in a 9.1m sprint. Faigenbaum et al.

(2007) found the plyometric group increased their sprint time by 0.3 second and also discovered a decrease in the 20 yard shuttle of 0.2 seconds. Faigenbaum et al. (2007) indicated that the differences between the findings of the two runs were due to the degree of the runs. The 20 yard shuttle run caused the subjects to change directions, going from the acceleration phase to the deceleration phase while the 9.1m sprint required the subjects to sprint in one direction that in turn was believed to be too short for one to reach his or her maximum running velocity.

In Dean, Nishihara, Romer, Murphy & Mannix (1998) study, on junior varsity and varsity athletes on the efficacy of plyometrics on improving athletic performance over four weeks. Dean et al. (1998) pre and post-test design, found that there was an overall .15 decrease for the 139 subjects (.1 second in girls and .16 seconds in boys) in the 20 yard run. The time frame of the study was short in comparison to the other studies. Dean et al. (1998) suggested that while the improvements were minor, they have the potential of being greater if conducted over a longer period of time.

Theses indicate that sprint velocity can decrease or increase through the usage of plyometric training depending on the length of the study as well as the sprinting distance (Diallo et al., 2001; Dean et al., 1998; Faigenbaum, 2007; Kotzamanidis, 2006; Robinson et al., 2004; Thomas et al., 2009).

Mechanisms Underlying Improvement in Power Muscle Contraction

Power and power performance is evaluated in plyometric training primarily by vertical jump height testing however there are times when the Margaria-Kalamen power test is used. It was consistently used in plyometric testing due to its reliability, simple formulas and instructions.

A study by Santos & Janeria (2008) looked at the effects of complex training on strength in male adolescent basketball players over 10 weeks with two sessions a week. The pre-post-test deign found an improvement in vertical jump height in three of the different jumps; squat jumps, depth jumps and countermovement jumps. Santos & Janeria (2008) also found an increase in the experimental group of 3.22 cm (squat jump), 3.14 cm (countermovement jump) and 1.93cm (depth jumps) with the control group decreasing in all of the jumps;(-1.96 cm squat jump, -2.36 cm countermovement jump and .036cm depth jump). According to Santos & Janeria (2008) all of the three jumping styles will increase vertical jump height in experimental group. Santos & Janeria (2008) hypothesized that the changes in vertical jump came from the athletes adherence to the usually design program which implemented increased changes in coordination, muscular strength and an improvement in synchronization of the segments.

Faigenbaum, (2007) found a greater improvement in vertical jump height on countermovement jump on males than Santos & Janeria (2008). Faigenbaum, (2007) found that vertical jump height increased in their male subjects by 3.4cm over six weeks, one session a week with one set weeks 1,3,5 and two sets weeks 2,4,6. Faigenbaum, (2007) hypothesized that the findings in vertical jump height came from the lower body plyometric exercises. Exercises that involves jumping off a box or surface then jumping vertically as quickly as possible.

Another study by Thomas et al. (2009) evaluated vertical jump height in youth soccer players on depth jump and countermovement jumps found similar results. Thomas et al. (2009) looked at male soccer players over six weeks with two sessions a week, found an increase in both depth jumps (2cm) and countermovement jumps (3cm) in vertical jump height. The subjects performed exercises that required them to drop from a certain height (depth jump group) or performed exercises with flexion of the knee (countermovement group) with 80 foot contacts initially at the beginning of the training period to eventually 120 foot contacts at the end of the training period. According to Thomas et al. (2009), there is not a difference between the two training modes of depth jump and countermovement jump for improving vertical jump height in youth soccer players. The improvement in vertical jump height was due to the increase in leg power from the adaptation of the plyometric exercises.

Diallo et al. (2001), found the same increase in countermovement as Faigenbaum, (2007) in prepubescent soccer players. There was a 3.4cm increase in the countermovement jump and 2 cm increase in the squat jump on vertical jump height in the experimental group with a 1cm decrease in countermovement jump and squat jump in the control group. Training sessions were three times a week with 200 jumps for week 1-5 with 300 jumps weeks 5-10. Training sessions were jumping, bouncing and skipping exercises. According to Diallo et al. (2001), the 10 week plyometric training study was long enough to bring significant increases in the experimental group than the control group. Higher training loads and volumes improve jump performances in prepubescent soccer players.

In a study by Dean et al. (1998) the authors reported smaller improvements in countermovement jumps on recreational year-around athletes at a sports camp. There was a 1.6cm increase in vertical jump height overall for the 139 subjects (1.04 cm increase in girls and 1.8 cm increase in boys). Training sessions were twice a week for 90 minutes. The sessions involved plyometric, reaction and agility drills. Dean et al. (1998) hypothesized that the shorter duration of time allowed for the improvements within their study which was due to strength gains occurring during the first week. A short training program can elicit improvements in performance when agility, reaction and plyometrics are incorporated or the physiological characteristics of the subject are below normal.

Kotzamanidis, (2006) found greater gains than did Dean et al. (1998), Diallo et al. (2001), Thomas et al. (2009), Faigenbaum, (2007) and Santos & Janeria (2008) in their studies regarding vertical jump height. Kotzamanidis, (2006) found a 7.97cm increase in vertical jump height in the experimental group with a decrease of .66 cm in the control group. Kotzamanidis, (2006) used Ergojump Bosco-System with a digital timer and contact matt for collecting their vertical jump height measurements. Santos & Janerira (2008) used Globus Ergo tester (Codogne, Italy), Dean et al. (1998) and Faigenbaum, (2007) used Ver-Tec system (Sports, Imports), Diallo et al., (2001) used a digital timer and contact mat and Thomas et al. (2009) used a Takei Jump Meter (Japan) in collection of vertical jump heights. Vertical jump heights have been measured via numerous mechanisms. According to Kotzamanidis, (2006), the enhancement in vertical jump height could be caused by un-matured neuromuscular system and more compliant elastic tissue within them than adults.

Other studies were conducted on vertical jump height performance on plyometric training in two different environments, land and the pool. These studies found greater and in some cases smaller increases in vertical jump height on the land environment.

Stemm & Jacobson, (2007) when comparing land based versus aquatic based plyometrics on vertical jump height on recreationally active adults over six weeks found, a 6 cm (67cm to 73 cm) increase in the land based group with a 1 cm (62 to 63) increase in the control group. Stemm & Jacobson (2007) speculate their findings were large due to the brief training period and the characteristics of the subjects which allowed for the neural adaptation to occur.

Robinson et al. (2004) also studied land versus aquatic based plyometric training on recreational active adults, over eight weeks. The land based group of 15 increased their vertical jump height by 10.6cm (32.6 to 43.2cm). Robinson et al.(2004) hypothesized the gains found within the study were due to the training mimicking preseason strength and conditioning programs that increases the intensity and workload for the enhancement in performance with similar improvements in aquatics.

Another study that compared land versus aquatic based plyometrics on recreational active adults, over eight weeks was conducted by Miller, Berry, Bullard & Gilders (2002). Vertical jump height scores were converted into power using the Lewis Nomogram formula. The land based group of 13 increased their vertical jump height by 15.7W (1046.5W to1062.2W) with an increase in the control group of 18W (1229.8W to 1247.9W). The Margaria-Kalamen stair test was taken by the subjects as well. The land based group increased by 8.9W (1239.5W to 1248.4W) with the control group increasing

26W (1434.9W to 1460.9W). Miller et al. (2002) hypothesized that land based plyometrics improve muscular power through the heavy loads brought on the body from its contact however there are greater improvements in aquatics.

All modes of plyometric training have shown improvements within vertical jump height, however the improvement is quite variable due to selected mode of training and equipment (Dean et al., 1998; Diallo et al., 2001; Faigenbaum, 2007; Kotzamanidis, 2006; Miller et al., 2002; Robinson et al., 2004; Santos & Janerira, 2008; Stemm & Jacobson, 2007; Thomas et al., 2009).

Mechanisms Underlying Improvement in Strength Muscle Contraction

Although muscular strength is directly associated with plyometrics it is rarely explored in adolescent athletes. There are currently two research studies that examined the effect of muscular strength on performance in adolescent athletes.

Triplett, Colado, Benavent, Alakhdar, Mandera, Gonzalez & Tella (2009) examined force development in seven areas in adolescent handball players over 4 days. There were three experimental groups; dry land, aquatic and aquatic with devices. The dry land based group had the greatest impact force of 1503.4N than the aquatic jump of 829.1N and aquatic jump devices 557.7N while the impact force development were greater in the dry land group of 19358.2 N/s with 4043.1N/s in the aquatic jump and 3926.8N/s aquatic jump devices group. Triplett et al. (2009) suspected that the greater findings originated from the bodyweight being larger than in the other two experimental environments.

In the study by Herro, Izquierdo, Maffiuletti and Garcia-Lopez (2006) focusing on electromyostimulation and plyometric training in sprint and jump time found a significant increase in maximal isometric strength (MVC) of 9.1% after training and 8.1% after detraining in the electromysostimulation group (EG). There were four training groups EG, PG (plyometric), EMG (combined) and P (EPG) with a control group. Although there was an increase in EG on MVC, the plyometric group (PG) saw no significant increases. The PG decreased after training and then increased after detraining.

One other study was conducted on muscular strength in plyometric training in young recreationally active adults on two different environments, land and the pool. This study found similar results in peak torque production.

Robinson et al. (2004) examined peak torque in extension and flexion on young recreationally active adults over eight weeks. The land based group performed an isokinetic strength test on the knee extensors and flexors on the subject's dominant leg. There was a significant increase in the land based group from pre to midtraining and midtraining to post-training in both extension (pre 94.8 Nm60.s-1, mid 108.0 Nm60.s-1, mid 108.0 Nm60.s-1, post 137.0) and flexion (pre 185.0 Nm60.s-1, mid 202.0 Nm60.s-1, mid 202.0 Nm60.s-1, post 230.0) with a consistent increase throughout the study (Extension: pre 94.8 Nm60.s-1, mid 108.0 Nm60.s-1, post 137.0 Nm60.s-1, Flexion: pre 185.0 Nm60.s-1, mid 202.0 Nm60.s-1, post 230.0 Nm60.s-1) . According to Robinson et al. (2004) this was the first study of its kind to examine torque velocity, power and performance the increases in mid training could be due to their population pool.

Muscular strength has been explored in active adults and athletes. It has been shown to improve one's strength by 258.5 lbs over a 12 week period with 4 to 12.8% of strength gains over a 10 week period when evaluated in Olympic style weight lifting and plyometric training programs (Markovic et al., 2007; Moore et al., 2005; Toumi et al., 2004). Muscular strength improves isokinetic strength in adolescent athletes up to 9.1% (Herro et al., 2006). There is currently not enough research conducted on isokinetic strength to further interpret theses results.

Muscle Injury and Damage

Plyometrics training requires constant contact on a surface. The body is repetitively jumping, hopping, bounding and pounding forcefully on the ground throughout its training (Chu, 1992). The ability to recover during plyometric training can be compromised with the short break duration. The high intensity repetitive motions used by plyometrics, induces muscle breakdown and damage (Stemm & Jacobson, 2007). Although plyometric training enhances power, strength, sprinting speed and technique, it has been shown to impair muscle function due to onset of muscle soreness, damage and injury.

Robinson et al. (2004) study on recreational active adults found that the onset of muscle soreness increased in the land based group over the eight weeks. The subjects muscle soreness and pain sensitivity were assessed only twice over six weeks. Assessments were taken at 0, 48 and 96 hours at baseline, week three and six with an algometer and self reported scale at the end of the training session. The muscle soreness scale ranged from 1(no soreness) and 10 (extreme soreness). The land based group muscle soreness increased throughout each testing period (Rectus femoris: week 1; 2.5, 5, 2.75, week 3; 1.5, 4.2, 3.9, week 6; 1.5, 4.5, 2.5, Biceps femoris: week 1; 2.5, 4.3, 3.5, week 3; 1.4, 4, 3.8, week 6; 1, 4.2, 2.9, Gastrocnemius: week 1; 2.2, 5.2, 4.8, week 3; 1.8, 4.7, 4.8, week 6; 1, 4.8, 3.8) and pain sensitivity (Rectus femoris: week 1; 5.1, 2.4, 3, week 3; 5.2, 2.8, 3.1, week 6; 5.3, 3.2, 3.3, Biceps femoris: week 1; 5, 2.5, 3.1, week 3; 5.2, 2.8, 3.5 , week 6; 5.2, 2.8, 3.5, Gastrocnemius: week 1; 4.1, 1.8, 2.1, week 3; 4.2, 2, 2.5, week 6; 4.2, 2.3, 2.4). Robinson et al. (2004) speculated that as intensity increased within the training there was increased muscle soreness and pain sensitivity within the lower extremity. Pain sensitivity started and oscillated with increases in training volume and intensity.

Miller et al. (2002) also conducted a study on recreational active adults and found opposite results to Robinson et al. (2004) study. There were no significant increases in muscle soreness throughout the eight week study. Muscle soreness was assessed 24, 48 and 72 hours after post-training with a muscle soreness scale ranging from 1(no soreness) and 10 (extreme soreness). Miller et al. (2002) speculated that the significant increase was not found in the land group, was due to the increase in volume was done equally between the two groups.

Muscle injury and damage has been shown to rise through plyometric training through the constant pounding on the surface (Miller et al., 2002; Robinson et al., 2004; Stemm & Jacobson, 2007). The rate of damage and injury has yet been examined fully.

Review of Aquatic Plyometrics

Aquatic exercise is becoming more commonly used as a form of exercise, similar to aerobic dance, jogging and fitness training (Sova, 2000). Aquatic exercises are usually defined as exercises that are completed in the vertical position with an individual chest or shoulder deep in water (Sova, 2000). Aquatic exercises tend to impose less impact on an individual's body than land based exercise (Martel et al., 2005; Miller et al., 2002; Miller et al., 2007; Robinson et al., 2004; Triplett et al., 2009). The reduction on impact comes from the buoyancy that is created from the water's displacement. Conversely, it is the water density that increases the resistance and causes the body to work harder thereby giving the individual a greater workout.

Aquatic exercises have been shown to be beneficially reduce impact forces on joints and internally and a good method for conditioning. Buoyancy provides the force on the body when submerged in an upward direction. That force reduces the subjects' weight along with the amount of force being applied on their joints in the landing phase (Miller et al., 2002; Miller et al., 2007; Robinson et al., 2004; Triplett et al., 2009). The buoyancy and resistance from the viscosity of the water allows for movement to be conducted weightless due to the resistance and force being equal (Miller et al., 2007). Aquatic exercises have been shown to be just as beneficial as land exercises.

There are currently no negative effects reported with aquatic plyometrics. All of the current research falls in agreement with Robinson and others' (2004) study on land versus aquatic plyometrics on power, torque, velocity and muscle soreness, that aquatic plyometrics provided the same improvements as well as greater improvements in some variables with a reduction in muscle soreness than land (Colado et al., 2009; Martel et al., 2005; Miller et al., 2002; Miller et al., 2007; Stemm & Jacobson, 2007; Triplett et al., 2009). Although there are no reports of any drawbacks with plyometric training, the amount of research on aquatic plyometrics is limited. Currently there are only eight studies that have examined the effects of aquatic plyometric training with only three of them conducted on adolescent athletes.

Types of Training Plans in Aquatics

Exercise training programs for aquatic training were conducted in chest or waist deep conditions. Training ranged from 20 minutes to an hour or 80 to 140 foot contacts (Bishop et al., 2009; Colado et al., 2009; Martel et al., 2005; Miller et al., 2002; Miller et al., 2007; Stemm & Jacobson, 2007; Triplett et al., 2009). Aquatic exercise training programs have yet been established as land based plyometrics. Currently there is not a consensus on which of the two training plans used in aquatic plyometrics is the best to follow when conducting aquatic plyometrics.

Length of Training Plans in Aquatics

Land based plyometrics have a duration of 6-12 weeks of 2 to 3 sessions a week (Breezo et al., 1988; Dean et al., 1998; Diallo et al., 2001; Markovic, 2007; Markovic et al., 2007; Santos & Janeira, 2008; Thomas et al., 2009). Although current research shows a variance of aquatic exercise training and land based plyometric training, aquatic plyometric training duration rage between 6 to 8 weeks with 2 to 3 sessions occurring a week (Bishop et al., 2009; Colado et al., 2009; Martel et al., 2005; Miller et al., 2002; Miller et al., 2007; Robinson et al., 2004; Stemm & Jacobson, 2007) with the exception of Triplett et al. (2009) study, duration lasting for less than 1 week. In adolescent athletes the duration is 6 or 8 weeks with 2 sessions a week occurring.

Percent of Improvements in Aquatics

Aquatic plyometrics have enhanced performance outputs in athletes. Currently there is not enough research conducted on the rate of improvements in aquatic plyometrics on adolescent athletes. Currently there are only three studies that have examined the affects of aquatic plyometrics on adolescent's athletes. There are five other aquatic studies that were conducted on recreationally active adults. Aquatic plyometrics has been shown to improve vertical jump by 3.5cm in adolescents (Martell et al., 2005). It has also been shown to increase muscular power, force and vertical jump in active adults (Colado et al., 2009; Miller et al., 2002; Miller et al., 2007; Robinson et al., 2004; Stemm & Jacobson, 2007). With there being a lack of literature on the improvements within aquatic plyometrics on adolescent athletes, the percent of improvements has yet been established let alone addressed.

Mechanisms Underlying Improvement in Muscle Mass in Aquatics

There is currently one study that examined the affect of aquatic plyometric training on muscle mass on young recreationally active adults. Colado, Tella, Triplett & Gonzalez (2009) study investigated muscular mass changes in a group 12 subjects over an eight week period. Body composition changes were observed. The aquatic group increased body weight by (.814 lbs) and fat free mass (2.816 lbs) with a decrease in percent body fat of (2.904 lbs) and fat mass (.91kg). The control group decreased in free fat mass (3.124 lbs), fat mass (.044 lbs) and body weight of (3.168 lbs) with an increase in percent body fat of (.264 lbs). Colado et al. (2009) found that the short resistance training program increased fat free mass in the aquatic group.

Mechanisms Underlying Improvement in Velocity in Aquatics

Velocity is known as the change of displacement over time. In order for velocity to increase within the muscle the change in displacement must be greater than the time of the action. Velocity is associated with explosive movements. Due to plyometric training allowing an individual to improve their explosiveness, velocity and dynamic performance is one of plyometrics common component in its training. There are currently two studies that have examined the effects of aquatic plyometrics, one conducted on adolescents while the other conducted on recreational active adults.

Bishop, Smith, R., Smith, M. & Rigby (2009) study conducted on adolescent swimmers. The eight week pre to post test design found that velocity changed differently between the two groups. The 5.5m sprint decreased .59s (3.88-3.29) in the aquatic plyometric group and the habitual training group decreased .12s (3.94-3.82) from pre to post training. Bishop et al. (2009) hypothesized explosive power training found in plyometrics, when combined with customary aquatic training could have a larger impact on a swimmer's quickness than habitual training.

In Robinson et al.(2004) study conducted on recreational active adults and found a .41second increase (6.15 -6.56) in aquatic group and a .38 second (5.97 -6.35) increased in the land based group in the 40m sprint time from pre to post training. Robinson et al. (2004) hypothesized that aquatic plyometric training could have similar gains as land based plyometrics which therefore could improve power, velocity and torque just as well as land based plyometrics.

Sprint velocity has been shown to increase through aquatic plyometrics (Bishop et al., 2009; Robinson et al., 2004). There is currently not a study that has examined the effect of aquatic plyometrics on velocity in adolescent athletes.

Mechanisms Underlying Improvements in Power in Aquatics

In Martel, Harmer, Logan & Parker (2005) on high school female volleyball players over six weeks found an increase in vertical jump height. The athletes were tested before and after training. There was a 3.7 cm increase (33.4 to 37.1) in vertical jump in the aquatic group with a 1.3cm increase (31.9 - 33.2) in the control group. Martel et al. (2005) hypothesized that vertical jump height would be higher in the aquatic group than the land based group. The findings from the study did conclude with what the researchers projected. The aquatic group improved by 11% percent in vertical jump height over the six week training period with the control group improving by 4%. Martel et al. (2005) study was the first research study to reveal aquatic plyometric improvements in adolescent athletes.

Stemm & Jacobson (2007) also studied the vertical jump except their study was conducted on recreationally active adults with a land based plyometric group. Vertical jump height performance increased greater than did Martel et al. (2005). The aquatic group increased 6cm (68 - 74) with an increase of 6cm in the land based group (67 -73) and 1 cm (62 -63) in the control group. Stemm & Jacobson (2007) speculate their findings were large due to the brief training period and the characteristics of the subjects which allowed for the neural adaptation to occur.

In a study by Miller, Cheatham, Porter, Ricard, Hennigar & Berry (2007) examined vertical jump performance and average power of the squat, countermovement and drop jump on young recreational active adults at chest and waist deep measurement heights. There were three groups; 1) chest deep; waist deep; and 3) the control group. There was an increase in both of the experimental groups (1cm increase in chest deep (40.9 - 41.9) and 2.5cm in waist deep (46.5 - 49.0) and a 2.1 decrease (54.9 - 52.8) in the control group. Average power in the chest deep group increased form squat jump and countermovement jump more than the waist deep group. Drop jump decreased in both experimental groups with waist deep having a significant decrease (1321.0W - 1113.4W).The control group decreased in both the squat jump and countermovement jumps. Miller et al. (2007) proposed that the lack of significance found in their study was due to their participants not refraining from strength training and other athletic activity while participating in their study.

Robinson et al. (2004) found greater results than Stemm & Jacobson (2007) study on vertical jump performance in young recreational active adults. Both of the two experimental groups increased in vertical jump height. Aquatic based group increased by 10.7 cm (31.9-42.6) with a 10.6 cm increase (32.6-43.2) in the land based group. Robinson et al.(2004) hypothesized the gains found within the study were due to the training mimicking preseason strength and conditioning programs that increases the intensity and workload for the enhancement in performance with similar improvements in aquatics.

In a study by Miller et al. (2002) vertical jump height measurements were converted over to power using the Lewis Nomogram formula on young recreational active adults. There was an increase in both of the experimental groups and control group. Aquatic based group increased their vertical jump power by 37.3W (1055.4-1092.7), 15.7W (1046.5-1062.2) in the land based group and 18W (1229.8-1247.9) in the control group. The Margaria-Kalamen power stair test was conducted and there was a significant increase of 87.3W (1216.8-1304.1) in the aquatic group. Miller et al. (2002) speculated that lighter loads applied on the body with faster training stimulus enhances velocity and power within therefore the which might explain why the aquatic group was able to increase power performance.

Power and power performance has been shown to improve through plyometric training. The rate of improvement from the training is not consistently known. However all of the improvements shown are directly affective in improving performance.

Mechanisms Underlying Improvement in Strength in Aquatics

There are currently two research studies that examined the effect of muscular strength on performance in adolescent athletes. In the Triplett et al., (2009) study the aquatic jump group and aquatic jump devices group had greater rate of force than the other experimental group in five of the seven areas. Time to; push, concentric, peak force were greater of .46s, .38s and 806.8N in the aquatic jump devices group than in the aquatic jump group of .41s, .34s and 713.2N and the dry land group .46s, .33s and 492N.

Aquatic jump group had a greater time to peak impact of .22s than in the aquatic jump devices of .16s and dry land group of .08s. Triplett et al. (2009) hypothesized the greater impact found within the aquatic groups more than in the dry land group were due to the intensity developed during the single leg jumps.

In the Martel et al. (2005) study, the authors found similar results to the Triplett et al. (2009) study on high school volleyball players that examined the effects of strength in power aquatic plyometrics through an isokinetic peak torque test. The subjects' leg strengths were measured in the form of the concentric peak torque on the dominant and non-dominant legs at knee extension and flexion oat 60deg.s-1 and 180deg.s-1. Concentric isokinetic peak torque significantly increased in both legs throughout the entire study with knee flexion and extension at 60deg.s-1being the greatest (dominant leg: knee flexion; pre 58Nm, post 70Nm, knee extension; pre 94Nm, post 106Nm, non-dominant: knee flexion; pre 57Nm, post 68Nm, knee extension; pre 80Nm, post 102Nm). Martel et al. (2005) hypothesized that concentric peak torque would be greater in the aquatic group.

Robinson et al. (2004) conducted a similar study on land versus aquatic plyometrics examine isokinetic strength on the dominant leg in young recreationally active adults. Isokinetic tests were done on the knee extensors and flexors pre, mid and post-training. There was a significant increase in only pre to midtraining (Extension: pre 96.8 Nm60.s-1, mid 119.0 Nm60.s-1, flexion: pre 188.0 Nm60.s-1, mid 209.0 Nm60.s-1) and midtraining to post-training in both extension and flexion (extension: mid 119.0 Nm60.s-1, post 147.0 Nm60.s-1, flexion: mid 209.0 Nm60.s-1, post 235.0Nm60.s-1) with a consistent increase overall in both groups(Extension: pre 96.8 Nm60.s-1, mid 119.0 Nm60.s-1, post 147.0 Nm60.s-1, flexion: pre 188.0 Nm60.s-1, mid 209.0 Nm60.s-1, post 235.0Nm60.s-1). According to Robinson et al. (2004) this was the first study of its kind to examine torque velocity, power and performance on one population with data being collected throughout the study.

Muscular strength improves isokinetic strength in adolescent athletes' dominant leg over six weeks of training (Martel et al., 2005). There is currently not enough research conducted on isokinetic strength to make a definite conclusion.

Muscle Injury and Damage in Aquatics

Aquatic plyometric training provides non-impact forces on the body. The density of the water creates a resistance for the body while buoyancy reduces the forces during landing (Martel et al., 2005, Miller et al., 2002; Miller et al., 2007; Robinson et al., 2004; Sova, 2000). The buoyancy within the water allows for a safer, comfortable joint landing than land based training (Miller et al., 2002). Aquatic plyometric training enhances power, strength, sprinting speed, technique and it has been shown to reduce the onset of muscle soreness, damage and injury.

The Robinson et al. (2004) study on recreational active adults found that the onset of muscle soreness increased in the land based group over the eight weeks. The subjects muscle soreness and pain sensitivity were assessed only over six weeks, assessments at 0, 48 and 96 hours after training for week one, three and six with an algometer and self reported scale at. The muscle soreness scale ranged from 1(no soreness) and 10 (extreme soreness). The aquatic based group muscle soreness decreased throughout each testing period (Rectus femoris: week 1;3, 2, 1.5, week 3; 1.5, 1.6, 1.5, week 6; 1.5, 1.2, 1, Biceps femoris: week 1; 3, 2.5, 1.2, week 3; 1.3, 1.4, 1.3, week 6; 1, 1.1, .9, Gastrocnemius: week 1; 2.2, 2.3, 1.2, week 3; 1.8, 1.7, 1.6, week 6; 1.2, 1.1, 1) and pain sensitivity (Rectus femoris: week 1; 5.1, 4, 4.5, week 3; 5.3, 4.2, 4.5, week 6; 5.3, 4.3, 4.4, Biceps femoris: week 1; 5.1, 4, 4.5, week 3; 5.1, 4.2, 4.8, week 6; 5.2, 4.3, 4.9, Gastrocnemius: week 1; 4.1, 3.2, 3.5, week 3; 4, 3.1, 3.9, week 6; 4, 3.6, 3.8). Robinson et al. (2004) hypothesized that the aquatic plyometric group incurred significantly less amount of muscle soreness due to water bouyancy.

Miller et al. (2002) also conducted a study on recreational active adults and found opposite results to Robinson et al. (2004) study. Miller et al. (2002) hypothesized that there would be a reduction in muscle soreness in the aquatic group. There were no significant differences in the aquatic and land based group in muscle soreness throughout the eight week study. Muscle soreness was assessed 24, 48 and 72 hours after post-training with a muscle soreness scale ranging from 1(no soreness) and 10 (extreme soreness). Miller et al. (2002) findings did not coincide with what they hypothesized although previous studies were more conclusive.

Muscle injury and damage has been shown to decrease through aquatic plyometric training (Martel et al., 2005, Miller et al., 2002; Miller et al., 2007; Robinson et al., 2004). The rate of damage and injury has yet been examined fully.

Summary

Plyometric training increases strength, power, velocity and sprinting speed. High intensity plyometric training improves vertical jump heights, sprinting speeds, strength as well as muscle hypertrophy. Although plyometric training enhances muscular fitness its down fall is the increase onset of muscle soreness and damage with the increased risk of injury in the lower extremity. However, aquatic plyometric training has been shown to have the same improvements as land based plyometrics without the risk of injury in the lower extremity. Studies suggest that the water buoyancy allows the body to overcome the constant force being applied on every impact. Therefore aquatic plyometric training should cause a greater improvement than land based plyometric training. The lack of research conducted on aquatic plyometric training, the current findings in this area are still inconclusive. Research needs to be conducted on adolescent athletes to determine the extent of improvement on velocity in trained adolescent athletes.

Chapter 3

METHODS

The purpose of this study was to determine whether six weeks of land based or aquatic plyometric exercise training had an effect on vertical jump height, velocity, initial sprint start and muscle soreness in adolescent high school track and field athletes. Currently the research conducted on land vs. aquatic plyometrics involving adolescents is limited. The present study was conducted using stratified random sampling, a between group pre/post design. There were two training groups: 1) land based plyometric and 2) aquatic plyometric that were assessed over a six week period. The training sessions occurred twice a week at Monterey Trail High School and at Consumes River Community College in Elk Grove, California.

Subjects

Thirty-one experienced female and male track and field athletes from Monterey Trail High school were solicited for the study. The athletes ranged between 15 to 18 years of age. All athletes that participated in the study were sprinters, who competed in 100 to 400 meters events. The athletes submitted parental consent forms prior to their involvement in the study. The participation forms were approved by Sacramento State University. As student athletes one of their criteria was to exercise regularly. The criteria for exclusion in the study was: 1) history of surgeries or severe lower extremity injuries within the last 12 months; 2) water phobia's; and 3) non-competition for at least one season at the junior varsity or varsity level. The participants in the study had prior involvement in a pre-conditioning strength program that was conducted two months prior to the beginning of the study. Two of the participants were eliminated from the study due to their loss of athletic eligibility in week two of the training period.

Study Design

Thirty-one subjects were stratified randomly to the two training groups; land based plyometrics and aquatic plyometrics. The subjects were equally placed within the two groups. The subjects kept a dietary and physical activity log throughout the course of the study to account for any possible variances that may have occurred within the study. All of variables were measured at the same time of day at Monterey Trail High School for each testing period to control for diurnal variation. Each subject performed a vertical jump height test, 20m sprint, 10 meter block start and reported muscle soreness via a Likert type scale. The vertical jump height test determined the power of each subject. The 20 meter sprint determined the velocity rate of each subject. The 10 meter block start determined the initial velocity of each subject. The muscle soreness scale identified the amount of soreness reported by each subject. Pre testing measurements were performed one week prior to the initial training period and post testing measurements were performed 72 hours following the last training.

Plyometric Training

The athletes were introduced to each of the plyometric exercise prior to the start of the first training session. The training progression regimen (shown in Appendix A) consisted of tuck jumps, side-to-side hops, split jumps and bounds which were performed two days a week over six week period of time. The entire training session lasted 50 minutes and incorporated a 5 minute warm-up period, 40 minute training period and a 5 minute cool down period. Training lasted 40 minutes with the initial training program consisting of two sets of 10-40 reps in side-to-side hops, split jumps and bounds along with three sets of 30 second tuck jumps. Sets and repetitions were increased after week two by one additional set of tuck jumps and 10 additional reps in the other exercises. After week five, sets and repetitions were increased again by one additional set of tuck jumps with 10 additional reps in the others exercises (Bishop et al., 2009; Chimera et al., 2009; Faigenbaum et al., 2007; Miller et al., 2002; Santos & Janeira, 2008; Robinson et al., 2004; Thomas et al., 2009). Training periods were identical for both training groups but the training environments were different. Land based plyometric training was conducted on mondo (turf). The subjects exercised in a t-shirt, shorts or sweats and their running shoes. Aquatic plyometrics training was conducted in a waist deep pool and each subject exercised in a t-shirt and shorts in a swim trunks or swim suit.

All of the exercises were explained and demonstrated to each subject prior to the training period. Tuck jumps were performed when the subjects jumped maximally off the surface with their knees toward their chest and their feet tucked under their bottom. Side-to-side hops were performed when the subjects positioned their feet shoulder width apart, jump outward and back. Split jumps were performed when the subjects jumped off the surface maximally from the lunge position with their lead foot extended forward. Bounds were performed when the subjects positioned their feet shoulder width apart, faced forward, jumped maximally outward swinging their arms. All of the jumps were performed continuously within each set until completed. A 30 second break occurred between each set and a two minute interval was given between each exercise.

Prior to the start and finish of each training session, all subjects performed the same warm-up and cool down. The warm up consisted of jogging for three minutes, and perfoming some lower body exercises such as; leg swings front/back and side-to-side, head circles, toe circles, hip circles and arm swings, 10 in each direction. The cool down consisted of a five minute jog (Colado et al., 2009; Stemm & Jacobson, 2007).

Pre and Post Test Measurements

A pre and post test was used to examine vertical jump height, 10m block start and 20 meter sprint. Vertical jump height, 10m block start and 20 meter sprint were conducted on the same day with a 15 minute break between each. A pre, mid and post test was used to measure muscle soreness. Muscle soreness measurements were conducted 24 hours prior to vertical jump height, 10m block start and 20 meter sprint. Testing and training occurred at 3:30 pm each day. Exercise testing apparel was consistent throughout the study.

Muscle Soreness Measurement

Muscle soreness was analyzed via 7-point Likert type visual analogue scale that ranged from zero to six. A score of “0” reflected an absence of soreness in the lower extremity and a score of “6” indicated severe pain with a restriction of movement in the lower extremity. Muscle soreness was assessed 24 hours prior to the first training session at week one and week three and 72 hours following week six (Impellizzeri et al., 2007; Impellizzeri et al., 2008; Miller et al., 2002; Robinson et al. 2004).

Vertical-Jump Power Measurement

Vertical jump heights were evaluated using the VER-Tec jumping system (Sports Imports, Inc, Columbus, Ohio). The subjects base height measurements were recorded by having both feet placed together and reaching upward as high as possible with one arm. After the base height measurements were recorded, the height of the VER-Tec jumping system adjusted according to guidelines. The subjects completed three practice jumps following instructions to jump as high as possible while swatting the markers on the VER-Tec device. After the practice jumps were completed, three test jumps were performed by the subjects with a two minute recovery time between each jump (Dean et al., 1998; Faigenbaum et al., 2007; Luebbers et al., 2003; Miller et al., 2002; Miller et al., 2007; Moore et al., 2005; Stemm & Jacobson 2007). The difference between the base height and the vertical jump heights were recorded to the nearest .64 cm (.25 inches). The highest of the three jumps were used in the analysis.

10 Meter Block Sprint Measurement

Ten meter block sprints were evaluated with the FinishLinx timing system (Haverville, Ma). The subjects were given two practice trials to be performed at submaximal speeds. Three maximal effort sprints were performed by subjects in their normal block stance on the mondo (turf) outdoor track at Monterey Trail High school. The subject were given three race commands in track and field; 1) “runners to your marks”, where the subjects got down in their blocks in a comfortable position, 2)“set” where the subjects rose in their stance and 3) “go” where the subjects sprinted maximal out of the blocks. The subjects were given three minute full recovery periods between each sprint. The three sprints were averaged and the peak sprint was used in analysis (Impellizzeri et al., 2007; Impellizzeri et al., 2008; Kotzamanidis, 2006; Thomas et al., 2009).

20 Meter Sprint Measurement

Twenty meter sprints were evaluated with the FinishLinx timing system (Haverville, Ma). The subjects were given two practice trials to be performed at submaximal speeds. Three maximal effort sprints were performed by subjects in a three-point stance position, on the mondo (turf) outdoor track at Monterey Trail High school. The subject were given three race commands in track and field; 1) “runners to your marks”, where the subjects got down in a three-point stance where they were squatting half way with their least dominant foot in front, with the dominant foot behind and their left or right hand on the starting line in front of them, 2) “set” where the subjects rose in their stance and 3) “go” where the subjects sprinted maximally out of the stance. The subjects were given three minute full recovery periods between each sprint (Diallo et al., 2001; Impellizzeri et al., 2007; Kotzamanidis, 2006; Markovic et al., 2007; Thomas et al., 2009; Villarreal et al., 2008). The three sprints were averaged and the peak sprint was used in analysis.

Data Analysis

Experimental data from both groups were expressed via means and standard deviations. The statistical analysis was conducted in SPSS 13.0 for Windows (SPSS, Inc., Chicago, IL). The paired T-test was used to determine whether the null hypotheses of no difference between the groups were proven. A 2-way mix repeated ANOVA was used to determine if any significant differences exist between the land based plyometric and aquatic plyometric groups on vertical jump, sprints and muscle soreness over the six week training period. The Bonferrioni’s post hoc analysis was used to show what variables are different between the two groups. The level of significance was set at $p \leq 0.05$.

Chapter 4

RESULTS

This chapter focused on the findings of the present investigation by examining the relationships postulated to exist between the independent and dependent variables as they related to trained adolescent high school sprinters. The chapter was divided into five sections which respectively addressed the following dependent variables: muscle soreness; vertical jump height; 10 meter block sprint; and 20 meter sprint. Additionally an overall summary of the six week training period was included. The scores were analyzed using descriptive, bi-variant and multi-variant statistics. The purpose of this study was to determine whether land based or aquatic plyometric exercise training had an effect on vertical jump height, velocity, initial sprint start and muscle soreness in adolescent high school track and field athletes during their outdoor season. Thirty-one Monterey Trail track and field high school students were solicited for the study but only twenty-six were tested. Two subjects were excluded from the study due to the loss of eligibility in week 2. Two land based subjects were removed from the data analysis to create a consistency of subjects within the two experimental groups. Descriptive analyses of the subjects are presented in Table 1.

Table 1
Descriptive Characteristics of Subjects

	Aquatic		Land	
Variables	Mean	*SD*	Mean	*SD*
Age (yr)	15.8	1.0	16.8	1.1
Height (cm)	175.0	7.8	170.4	19.9
Weight (kg)	65.3	7.6	66.4	6.2

n = 13 for the Aquatic and the Land groups

Muscle Soreness

Muscle soreness was measured three different testing times (pre, mid, and post) over a 6- week training period using a Likert type scale (Table 2) that ranged from 0 (a complete absence of soreness) to 6 (a severe pain that limits my ability to move).

Table 2
Likert Scale of Muscle Soreness (Impellizzeri et al., 2007)

Value	Description
0	A complete absence of soreness
1	A light pain felt only when touches/a vague ache
2	A moderate pain felt when touched/a slight persistent pain
3	A light pain when walking up or down the stairs
4	A light pain when walking on a flat surface/painful
5	A moderate pain, stiffness or weakness when walking/very painful
6	A severe pain that limits my ability to move

Note. The scale emphasizes on the onset of muscle soreness not pains sensitivity

The results (Figure1) from the pre, mid, and post muscle soreness test showed that no significant difference existed between the land and the aquatic groups F (1, 24) = 2.349, = .138, partial η^2 .089. The mean scores for the pre test were: aquatic (M = 3.65, SD =1.01); and land (M = 2.88, SD =1.03). The mean scores for the mid test were: aquatic (M = 3.31, SD =1.03); and land (M = 2.69, SD = .855. The mean scores for post test were: aquatic (*M* = .62, *SD* = .77); and land (*M* = .77, *SD* = .73). Although the between scores were not significant, differences did exist in the within test scores.

The results additionally showed within subjects effect score for muscle soreness $F(2,48) = 95.74$, $p < .001$, partial η^2 .80 within the groups. The post hoc Bonferroni test revealed significant differences in aquatic pre (*M* = 3.65, *SD* = 1.0) to post (*M* = .62, *SD* = .77) test scores and mid (*M* = 3.31, *SD* = 1.03) to post (*M* = .62, *SD* = .77) test scores and land pre(*M* = 2.88, *SD* = 1.02) to post (*M* = .77, *SD* = .73) test scores and mid (*M* = 2.69, *SD* = .86) to post (*M* = .77, *SD* = .73) test scores.

The initial onset of muscle soreness in the aquatic group was .77 points higher than the land based group but the onset of muscle soreness dropped similarly in both groups from pre, mid and post test as shown in Figure1.

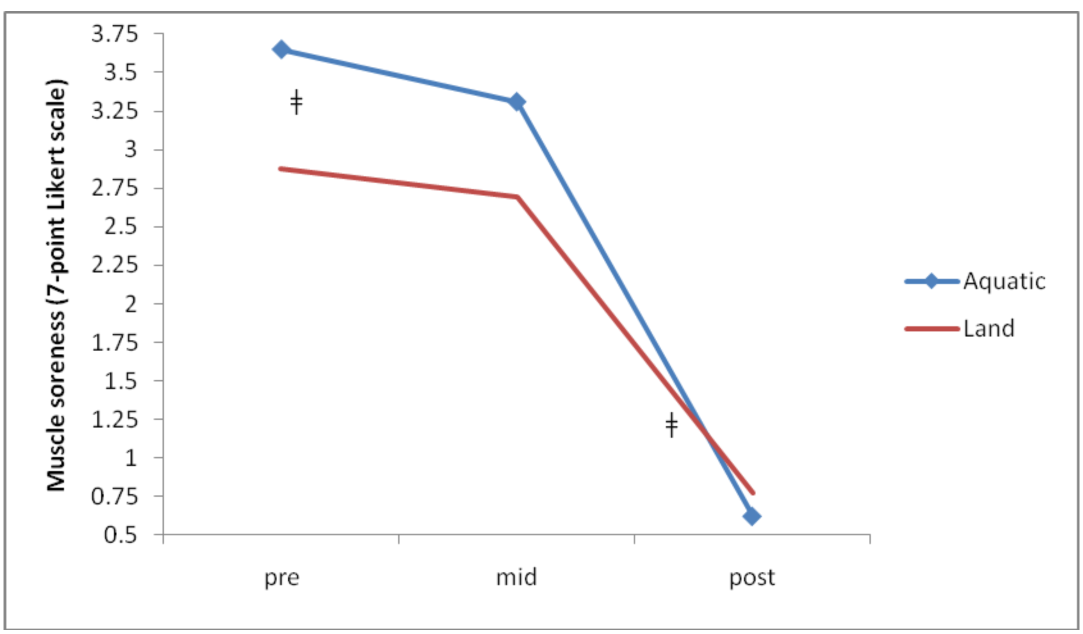

Figure 1. Muscle Soreness Land based vs. Aquatic based
‡ $p < 0.05$

Vertical-Jump

Vertical jump heights were comparable between the aquatic groups pre (*M* = 24.5, *SD* = 4.06) and post test (*M* = 24.73, *SD* = 3.9) to the land based groups pre (*M* = 23.23, *SD* = 5.09) and post test measurements (*M* = 23.46, *SD* = 5.32), *t* (25) = -2.90, *p* = .008 (two tailed). Although there were no significant differences between the two groups (Table 3), the aquatic group began jumping at a higher jumping height than did

Table 3
Pre/Post Test measurements of Aquatic and Land Based Plyometrics

Variable			Aquatic		Land		Total	
			M	*SD*	M	*SD*	M	*SD*
Pre	20m(s)	Trial 1	3.20	0.18	3.26	0.25	3.23	0.22
		Trial 2	3	0.6	3.32	0.23	3.16	0.47
		Trial 3	3.11	0.21	3.25	0.25	3.18	0.24
Post	20m(s)	Trial 1	3.26	0.15	3.29	0.32	3.27 ǂ	0.25
		Trial 2	3.04	0.32	3.28	0.27	3.16 ǂ	0.31
		Trial 3	3.07	0.32	3.31	0.28	3.19	0.32
Pre	10m(s)□	Trial 1	1.95	0.17	2.04	0.28	1.99	0.23
		Trial 2	1.9	0.18	1.97	□.19	1.94	0.18
		□rial 3	1.93	0.19	1.99	0□18	1.96	0.18
Post	10m(s)	Trial 1	1.86	0.1	2.01	0.20	1.9	0.20
		Trial 2	1.83	0.22	2.03	0.24	1.93 ǂ	0.25
		Trial 3	1.87	0.21	2.08	0.21	1.98 ǂ	0.23
Pre	VJ(m)		24.50	4.1	23.23	5.1	23.9	4.6
Pos□	VJ(m)		24.73	3.□	23.43	5.3	24.1	4.6

ǂ denotes significant alpha level of 0.05 within the experimental groups at post test (post hoc, after ANOVA)

the land based group Vertical jump height scores increased in both groups by .23cm from pre to post-test.

10 Meter Block Sprint

The 10 meter block consisted of a pre test and post test with three trials each per aquatic and land based plyometric group. The results from the pre 10 meter block showed that no significant difference exists between the aquatic and land group $F(1,24) = .947$, p = .340, partial η^2 .038 on the pre . Due to the violation of sphericity, the unit variety test Greenhouse Geisser, Epislon was adjusted to average the test of significance. The results indicated a non significant main effect $F(1.59, 38.149) = 2.741$, p = .088, partial η^2 .103. There were no significant within score differences found in the pre test l scores of trials 1, 2 or 3.

The results showed that the aquatic and land based plyometric groups were significantly different on the post block scores $F(1,24) = 5.538$, $p <.05$, partial η^2 .990. The post hoc Bonferroni test indicated significant differences from trial 2 to 3 as shown in Figure 2. The land based sprint times in trial 2 (*M* = 2.03, *SD* = .24) and trial 3 (*M* = 2.08, *SD* = .21) were slower than the aquatic group in trial 2 (*M* =1.83, *SD* = .22) and trial 3(*M* = 1.87, *SD* = .21). However, the results indicated no significant differences were found in the main effect scores of the post block $F(1.55,37.33) = 2.244$, p =.131, partial η^2 .085. Although sprint times increased in both groups in the trials the increase within the groups were very small (Table 3).

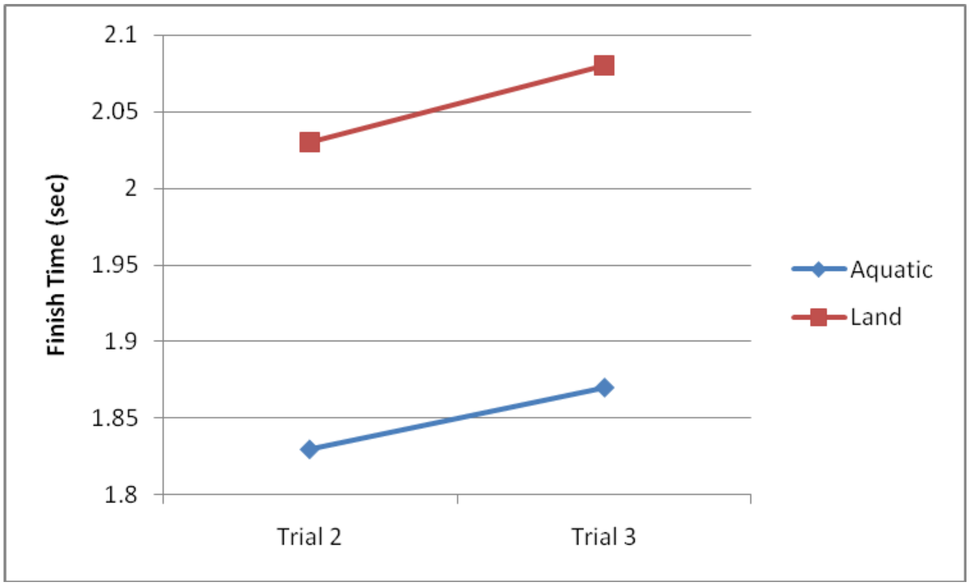

Figure 2. 10 meter block sprint in Aquatic and Land based groups (post-test).

20 Meter Sprint

The results from the pre 20 meter sprints showed no difference between the two groups, land and aquatic $F(1, 24) = 3.056$, $p = .093$ partial η^2 .113. Due to the violation of sphericity, the unit variety test Greenhouse Geisser Epislon was adjusted to average the test of significance. The results indicated a non significant main effect $F(1.098,26.358) = 2.00$, $p = .169$, partial, η^2 .077. There were no within score differences found within the pre trial scores of 1, 2 or 3.

The results found aquatic and land based plyometric groups were not significantly different in the post 20 meter sprints as well $F(1,24) = 2.922$, $p = .100$, partial η^2 .109. However, the results indicated a significant main effect within the 20m post sprint trials $F(2,48) = 3.749$, $p = .031$, partial η^2 .135. The post hoc test indicated there were significant differences from trial 1 to trial 2 (Figure 3). The aquatic groups sprint times in trial 1 (*M* = 3.26, *SD* = .15) and trial 2 (*M* = 3.04, *SD* = .32) were .24 seconds faster than the land based groups times in trial 1 (*M* = 3.29, *SD* = .32) and trial 2 (*M* = 3.28, *SD* = .27).

Figure 3. 20 meter sprint in Aquatic and Land based groups (post-test).

Summary

Aquatic and land based plyometrics did not significantly decrease sprinting speed and vertical jump height in trained high school track and field sprinters during their outdoor competition season. All but one of the hypotheses was rejected; there was no significant difference between the aquatic and land based plyometric group on the measure of speed in the 10 meter block sprint. The land based plyometric group had a greater increase in sprint time from trials 2 to 3 in post-testing when compared to the aquatic group in the 10 meter block sprint. All of the other hypotheses were rejected although both groups increased in the vertical jump heights, increased in the 20 meter sprints and decreased in the onset of muscle soreness at the conclusion of the study. There were two significant within effect differences found in the post testing trials, in the 20 meter sprint and the 10 meter block sprint. Both groups increased in their sprint times in the 10 meter block sprint with a decrease in the sprint time of both groups in the 20 meter sprint.

Chapter 5

DISCUSSION

Previous studies have shown significant increases in power, force and sprinting speed along with significant decreases in muscle soreness in plyometric training programs conducted over an eight to twelve week training period (Bishop et al., 2009; Colado et al., 2009; Diallo et al., 2001; Markovic et al. 2007; Miller et al., 2002; Robinson et al., 2004; Santos & Janeira, 2008). Moreover, numerous studies show that six week plyometric training programs also yield significant results within power, force and improves sprinting speed (Martel et al., 2005; Miller et al., 2002; Miller et al., 2007; Thomas et al., 2009). Many of these studies have reported greater gains in performance, 10m, 20m, 30m sprints and vertical jump height testing with aquatic plyometrics. The intent of this study was to determine whether land based or aquatic plyometric training programs had an effect on vertical jump height, velocity, block sprint and muscle soreness in trained high school adolescent track and field athletes during their outdoor competition season.

Contrary to expectations, no significant differences were found to exist between the two plyometric training groups; land based and aquatic. The main findings of this study was aquatic plyometrics did not have a greater impact on athletic performance than did land based plyometrics although its measurements and times were superior. Another surprising finding was the aquatic based training had no effect on vertical jump height performance improvements. Muscle soreness decreased throughout the training period within both groups. The block sprint post-testing had a between group effect trial score. The score increased from trial 2 to 3 in both the land and aquatic groups.

The present study is the first to report these effects in trained adolescent high school track and field athletes within the competition period of their outdoor season. This study may provide insight into whether plyometric training is a good training method to incorporate during or outside of competition season to enhance adolescent athletes performance.

Muscle Soreness

The intense contraction that occurs through the constant pounding caused by the force generated induces the rate of muscle breakdown and damage (Chu, (1992), Stemm & Jacobson, 2007). Because of the reduced impact of forces on the joints, the aquatic group was expected to reduce primarily more than the land based group. However, during this training period, this response was not shown by the subjects, but was rather reduced equally. Similar results were reported by Impellizzeri et al. (2008), Miyama & Nosaka (2004) and Robinson et al. (2004) observed an experimental group and a land based group and found that the experimental group had a lower Likert scale score but failed to detect any difference at ($p < .05$)

The likely mechanisms of aquatic plyometrics having lower muscle soreness values in previous studies were due to the time of season. Muscle soreness is reported to decrease aquatic training than does land based training because of the property of buoyancy. Buoyancy is the fluid based force applied during water activities. It allows for a reduction in the musculoskeletal system through buoyancy and viscosity components

(Miller et al., 2002; Sova, 2000). The fluid environment reduces the amount of stress on the lower extremities due to the reduction brought on by the increased training load. In the previously reported studies, the training periods were conducted in the pre-season and within no season for the recreational active adults whose work out periods were not as consistent.. The elicit amount of stress and high intensity training is significantly less in pre-season than in competition season. During competition season, the body is working at a maximal state consistently which in many cases generates a greater risk of injury. These reported benefits between the two groups did not occur in the present study.

Vertical-Jump

One primary benefit of plyometric training is the great increase in vertical jump height through the increased power output and rate of force development distributed to the stretch shortening cycle. The rate of force development has been reported to be greater in aquatic plyometrics than land based plyometrics (Martel et al., 2005; Miller et al., 2002; Robinson et al., 2004; Stemm & Jacobson, 2007). In the current study vertical jump height did not increase greatly with the aquatic group but rather rose to .23cm in both training groups. This is contradictory to the 2.5 cm, 3.5 cm, 6 cm, 10.7 cm and 21.6W increases found in only one experimental group, aquatics, in studies by Martel, Miller, Stemm & Jacobson and Robinson (Martel et al., 2005; Miller et al., 2002; Miller et al., 2007; Robinson et al., 2004; Stemm & Jacobson, 2007). The increase in vertical jump height reported in prior research may have been significantly different due to the longer aquatic plyometric training sessions conducted in comparison to the current study. Prior research have reported a minimum of 3.1% improvements in vertical jump height with aquatic based training, in training sessions lasting for more than 60 minutes (Colado et al., 2009; Martel et al., 2005; Miller et al., 2002; Miller et al., 2007; Robinson et al., 2004; Stemm & Jacobson, 2007). In the current study the training sessions were 50 minutes with only 40 minutes of the actual training regime occurring. This indicated the length of the training session was not sufficient enough to the plyometric training program to bring forth beneficial results.

Vertical jump height can also be affected by the jumping style performed. Countermovement jumps are utilized primarily in vertical jump testing due to the greater increase it has on the stretch shortening cycle of 7.5% to 8.7% (Markovic, 2007). This great improvement comes from the large amplitude of movement conducted by one moving in the upward direction toward the target above. However, the great improvements come with a potential bias within. Markovic (2007), meta-analysis reported the jumping technique for countermovements were not controlled for as well as the number of sessions per week while depth and squat jumps were. Although depth jumps and squat jumps reported a 4.7% of improvement in vertical jump height, Markovic reported the primary jump method utilized in plyometric training programs are still countermovement (Markovic, 2007). In this present study countermovement jumps were utilized but the rate of improvement was not found.

10 Meter Block Sprint

A paucity of research exists on block 10 meter block sprints and the research conducted has inconsistent findings. The current study found no difference between groups on the pre test while there was significant difference on the post test from trial 2 to 3. Both groups increased their sprint times by .04 in aquatic and .05 in land based group. Thomas et al. (2009) found no improvement change in sprint times with an increase of .02 for both experimental groups resulting from the training regime. However, Impellizzeri et al., 2007 and Kotzamanidis, 2006 reported improvements in sprinting speed of .08, .07 and .05 seconds in the experimental groups. The results in the current study are similar to the increase in sprint time for the experimental groups as the findings of Thomas et al., 2009. These results may have stemmed from the training period, sessions and sprinting variables being primarily identical. Another explanation could be the foot to ground contact. Ground contact times within plyometrics are rapid and quick. It is possible that in the current study, the foot to ground contact times were longer than expected thereby decreasing the power in the ground reaction forces produced in sprinting.

In the current study, a significant increase of .05 m/s was revealed in the within subject effect scores for both the land and aquatic groups. This may be explained by mean value scores individually reported for each of the trials. Prior studies indicated that all participants completed three trials in the testing sessions but only reported the best performance trial for analysis. Although there were no aquatic or aquatic versus land based plyometric studies that have examined the effect of the 10m initial sprint start, the findings in this current study are truly valuable for future research.

20 Meter Sprint

No significant differences were found between the aquatic and land plyometric groups in this study but there was a significant within effect trial scores uncovered between trials 1 and 2. This is contrary to the land based plyometric studies of Impellizzeri, Kotzamanidis, Markovic and Villarreal who found a significant decrease in sprinting time that elicited an improvement performance (Impellizzeri et al., 2007; Kotzamanidis, 2006; Markovic, 2007; Villarreal et al., 2008). As opposed to this, Thomas et al., 2009 found no change in sprinting speed while Diallo et al., 2001 reported a decrease in sprinting speed.

Sprinting speed is enhanced when there is a reduction in foot to ground contact with an increase in high force and high power production. This concept requires both the eccentric and concentric phase to occur rapidly. The lack of change in sprint performance in the current study may be due to the training period. Current studies support Kotzamanidis, 2006 and Delecluse et al.(1995) revealed that short sprint training (30 meters or less) with a full recovery period has a positive effect on running velocity over a long training period and it will enhance the sprinting speed in untrained subjects. Although this current study does not support previous findings, it is a study conducted on trained track and field sprinters.

Differences in the procedures may have also influenced the results. A plyometric sport- specific training was utilized in the current study, while all other studies employed resistant training. It is well known that plyometric and resistant training elicit a different increase in power and athletic training. Athletes are near their maximal adaptation point for strength in plyometrics while resistance training is performed at lower velocities than found during the competition phase (Martel et al., 2005). Plyometric training is performed at high velocity and power which decreases the foot to ground contact.

However, this was not the case in the present study and may not have been a determining factor.

Another difference in findings may have been the age of the subjects. The age requirement for one to participate in plyometric training has yet to become established. In the current study, the subjects ranged between the ages 15 to 18 years old. Due to the developmental changes that occur from pubertal to maturation, the difference in muscle mass, strength output, and neuromuscular activity are distinctively different. Primarily plyometric studies are conducted on adults with an exception of five studies that was conducted on adolescents (Bishop et al., 2009; Faigenbaum et al., 2007; Kotzamanidis, 2006; Martel et al., 2005; Santos & Janeira, 2008). Another contributing factor which may have influenced the results was the athleticism of the subjects. Untrained subjects have a greater increase of a learning effect onset occurring due to the training period being directly associated with the increase in pre to post measurements in comparison to trained subjects (Moore et al., 2005). In the current study all of the subjects were trained athletes.

Lastly, the timing of the study occurred during the track and field competition season. Competition season in track and field is very rigorous and the athletes are constantly and continuously exercising and performing at maximal levels. Current research shows that continuous ground impact forces and contraction brings forth an extensive amount of stress on the lower extremity which may lead to acute muscle soreness, musculoskeletal injuries and can decrease sprinting speed. Campo and others (2009) found no increases in kicking speed for adolescent soccer players when conducting their study during competition season. The current study found similar results in regards to sprinting speed.

Limitations & Recommendations

Six limitations were found that may have contributed to the findings of the current study. They were: 1) The sample was composed of high school sprinters who were between the ages of 15 to 18 ; 2) A control group was not used as part of the study; 3) The study contained only 26 subjects which limits the statistical power of the study; 4) There was a difference in years of track experience between the aquatic and land based groups, the land based group were mostly composed of “sophomores” while the aquatic group, were mostly “juniors and seniors”; 5) There was an age difference between the aquatic and land based groups, with the aquatic group having older participants than the land based group; and 6) The study was conducted during the competition phase of the season, a period of time when the sprinters are is peaking physiologically.

Investigation of whether the time of season that plyometrics is implemented in aquatics or land based plyometrics should be further examined. By determining the right time of implementing plyometrics within a season could further enhance power, strength and agility in an individual.

Conclusion

After six weeks of plyometric training the results showed that aquatic and land based training had similar scores in vertical jump height, 20 meter sprint and muscle soreness with an exception of 10 meter block post test scores. The 10 meter block sprint times improved more with the land based plyometric training group than did the aquatic plyometric training group. Despite the existence of no differences between the two groups on three of the four variables, both groups improved their scores with training thus indicating that both forms of training were effective. Aquatic plyometrics is commonly thought to be a more effective training mode than land based plyometrics due to the reduction of stress on the lower extremities as well as the ability to produce just as much force in water as on land. Despite the lack of significant difference between the two groups, the results of this study did highlight the potential of using either of the plyometric training programs to improve power and velocity in adolescent track and field sprinters. Although, the finding showed that the aquatic plyometric group out performed the land based plyometric group the findings between the two groups did not show the aquatic group to be significantly greater. Aquatic plyometric training is just as effective as the traditional land based plyometric training that is incorporated throughout multiple sport programs. Plyometric training is commonly utilized in pre and post seasons. However, future researchers should focus on the training period that the plyometrics is implemented. By investigating the time of season, the researcher can pin point the best time to implement plyometric training that will maximize the power, speed and agility that plyometrics is known for.

APPENDICES

APPENDIX A

Training Regimen

Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Tuck Jumps 3x 30 second jumps 30 sec rest between sets & 2mins between exercises	Tuck Jumps 3x 30 second jumps 30 sec rest between sets & 2mins between exercises	Tuck Jumps 4x 30 second jumps 30 sec rest between sets & 2mins between exercises	Tuck Jumps 4x 30 second jumps 30 sec rest between sets & 2mins between exercises	Tuck Jumps 4x 30 second jumps 30 sec rest between sets & 2mins between exercises	Tuck Jumps 5x 30 second jumps 30 sec rest between sets & 2mins between exercises
Side-to-Side Hops 2x 40 30 sec rest between sets & 2mins between exercises	Side-to-Side Hops 2x 40 30 sec rest between sets & 2mins between exercises	Side-to-Side Hops 2x 50 30 sec rest between sets & 2mins between exercises	Side-to-Side Hops 2x 50 30 sec rest between sets & 2mins between exercises	Side-to-Side Hops 2x 50 30 sec rest between sets & 2mins between exercises	Side-to-Side Hops 2x 60 30 sec rest between sets & 2mins between exercises
Split Jumps 2x 30 30 sec rest between sets & 2mins between exercises	Split Jumps 2x 30 30 sec rest between sets & 2mins between exercises	Split Jumps 2x 40 30 sec rest between sets & 2mins between exercises	Split Jumps 2x 40 30 sec rest between sets & 2mins between exercises	Split Jumps 2x 40 30 sec rest between sets & 2mins between exercises	Split Jumps 2x 50 30 sec rest between sets & 2mins between exercises
Bounds 2x10 30 sec rest between sets & 2mins between exercises	Bounds 2x10 30 sec rest between sets & 2mins between exercises	Bounds 2x20 30 sec rest between sets & 2mins between exercises	Bounds 2x20 30 sec rest between sets & 2mins between exercises	Bounds 2x20 30 sec rest between sets & 2mins between exercises	Bounds 2x30 30 sec rest between sets & 2mins between exercises

APPENDIX B

Informed Consent

AGREEMENT FOR TEAM PARTICIPATION

[Including Waivers and Releases of Potential Claims and Statement of Other Obligations]

All sections of this Agreement must be completed, with the signed original delivered to the School Office, before a Student will be allowed to participate in any manner in the Team Activities defined below. A separate Agreement is required for each Team in which the Student may participate.

Name of Student	Address:
Grade:	DOB:
School:	Telephone:
Team:	

In Consideration for the Student's ability to participate in the Team [including any Sport, Cheerleading, Dance, or Marching Band], including try outs for the Team, participation in Team practices or training sessions, receiving coaching, training, and direction, participating in Team events, shows, performances, and competitions, and traveling to and from any of the foregoing activities ("Team Activities"), the Student and the Parent or Legal Guardian ("Adult") signing this Agreement agree as follows:

1. It is a privilege, not a right, to participate in extra-curricular activities, including Team Activities. The privilege may be revoked at any time, for any reason, that does not violate Federal, State or District laws, policies or procedures. There is no guarantee that the Student will make the Team, remain on the Team, or actively participate in Team events, shows, performances, or competitions. Such matters shall remain exclusively within the judgment and discretion of the District and its employees.

2. The Student and the Adult understand the nature of the Team, including the inherent or potential risks of Team Activities. The Student is in sufficiently good health and physical condition to participate in Team Activities, and voluntarily wishes to participate in Team Activities. Before participating in a Team Activity, a medical clearance shall be submitted (valid for one calendar year), signed by a medical doctor (nurse practitioners, chiropractors or other non-California licensed medical doctors are not acceptable), stating that the Student has been physically examined and is deemed to be in sufficiently good health and fitness so that the Student may fully participate in Team Activities.

3. The Student shall comply with the instruction and directions of Team Activity teachers, coaches, supervisors, chaperones, and instructors. During the Student's participation in Team Activities, as well as academic and/or other school activities, the Student shall comply with all applicable Codes of Conduct. The Student shall also generally conduct himself/herself at all times in keeping with the highest moral and ethical standards so as to reflect positively on himself/herself, the Team and the District. Failure to meet these obligations may, in the discretion of the District, result in immediate removal from Team Activities and a prohibition against any future involvement in Team Activities or other extra-curricular activities. Should the violation of these obligations also result in bodily injury or property damage during a Team Activity, the Adult will (a) pay to restore or replace any property damaged as a result of the Student's violation, (b) pay any damages caused to bodily injury to an individual, and (c) defend, protect and hold the District harmless from such property damage or bodily injury claims.

4. Team Activities contain potential risks of harm or injury, including harm or injury that may lead to permanent and serious physical injury to the Student, including paralysis, brain injury, or death ("Injuries") Injuries might arise from the Student's actions or inactions, the actions or inactions of another Student or participant in a Team Activity, or the actual or alleged failure by District employees, agents or volunteers to adequately coach, train, instruct, or supervise Team Activities. Injuries might also arise from an actual or alleged failure to properly maintain, use, repair, or replace physical facilities or equipment available for Team Activities. Injuries might also arise from undiagnosed, improperly diagnosed, untreated, improperly treated, or untimely treated actual or potential Injuries, whether or not caused by the Student's participation in Team Activities. All such risks are deemed to be inherent to the Student's participation in Team Activities. By this Agreement, the Student and Adult are deemed to fully assume all such risks and, in consideration for the right of the Student to participate in Team Activities, understand and agree that to the fullest extent allowed by law they are waiving and releasing any potential future claim they might otherwise have been able assert against the District, or any Board Member, employee, agent or volunteer of the District ("Released Parties") by or on behalf of the Student or any parent, administrator, executor, trustee, guardian, assignee or family member, and further understand that transportation to or activities at another location are "field trips" or "excursions" for which there is complete immunity pursuant to Education Code § 35330.

5. If the Student believes that an unsafe condition or circumstance exists, or otherwise feels or believes that continued participation in Team Activities might present a risk of Injury, the Student will immediately discontinue further participation in Team Activities, notify School personnel of the Student's belief, and notify a parent or guardian of the Student's belief. Any parent or guardian of the Student shall, thereafter, not allow the Student to participate in Team Activities until the unsafe condition or circumstance is remedied, with any question or concern regarding the alleged existence of the unsafe condition or circumstance addressed to their satisfaction.

6. Emergency medical information regarding the Student is on file with the District and is current. The Adult agrees to provide updated medical information during the course of the Student's participation in Team Activities. If an injury or medical emergency occurs during Team Activities, District employees, agents or volunteers have my express permission to administrator or to authorize the administration of urgent or emergency care, including the transportation of the Student to an urgent care or emergency care provider. In such circumstances, notice to me and/or the Emergency Contact of the injury or medical emergency may be delayed. Therefore, any urgent or emergency care provider has my express authority to conduct diagnostic or anesthetic procedures, and/or to provide medical care or treatment (including surgery), as they may deem reasonable or necessary under all existing circumstances. All costs and expenses associated with such care are solely my responsibility.

7. Education Code Section 32221.5 requires us to notify you that: **Under state law, school districts are required to ensure that all members of school athletic teams have accidental injury insurance that covers medical and hospital expenses. This insurance requirement can be met by the school district offering insurance or other health benefits that cover medical and hospital expenses. Some pupils may qualify of enroll in no-cost or low-cost local, state, or federally sponsored health insurance programs. Information about these programs may be obtained by calling (800-431-1270).** Education code section 32221 requires that such insurance cover medical and hospital expenses resulting from bodily injuries in one of the following amounts: (a) a group or individual medical plan with accident benefits of at least $200 for each occurrence and major medical coverage of at least $10,000, with no more than $100 deductible and no less than 80% payable for each occurrence; (b) group or individual medical plans which are certified by the Insurance Commissioner to be equivalent to the required coverage of at least $1,500; or (c) at least $1,500 for all such medical and hospital expenses. You may meet this obligation in one of two ways:

Option 1: Private medical insurance. If this option is selected, please provide ________________________ (Name Insurer) and ________________________ (Policy number), ____________________________(list coverage dates or "continuous"). By signing below, the Adult is certifying that the Student is presently covered, and will remain covered during the length of the Team season, under the Policy, and the Policy complies with Section 32221.

Option 2: Purchase insurance meeting the requirements of Section 32221, for the period during which the Student is participating on the Team, through a coverage provider made available through the District [please contact the District to gain additional information regarding this program]. If you are financially unable to pay for such insurance, a payment waiver can be submitted [forms seeking this waiver are also available from the District]. If the waiver is submitted, it remains the obligation of the Student and Adult to ensure that such coverage is actually purchased; with the District assuming no liability or obligation arising from any actual or alleged failure timely to assist or obtain such coverage for the Student.

8. Employees, agents or volunteers of the District, members of the press or media, or other persons who may attend or participate in Team Activities, may photograph, videotape, or take statements from the Student. Such photographs, videotapes, recordings, or written statements may be published or reproduced in a manner showing the Student's name, face, likeness, voice, thoughts, beliefs, or appearance to third parties, including, without limitation, webcasts, television, motion pictures, films, newspapers, yearbooks, and magazines. Such published or reproduced items, whether or not for a profit, may be used for security, training, advertising, news, publicity, promotional, informational, or any other lawful purpose. I hereby authorize and consent to any such publications or reproductions, without compensation, and without reservation or limitation.

9. This Agreement shall be governed by the laws of the State of California. This Agreement is to be broadly construed to enforce the purposes and agreements set forth above, and shall not be construed against the Released Parties solely on the basis that this Agreement was drafted by the District. If any part of this Agreement is deemed invalid or ineffective, all other provisions shall remain in force. No oral modification of this Agreement, or alleged change or modification of its terms by subsequent conduct or oral statements, is allowed. This Agreement contains the sole and exclusive understanding of the parties, with no other representation relied upon by the Adult or Student in determining whether to execute this Agreement or in agreeing to participate in Team Activities.

BY SIGNING BELOW: (1) I AM GIVING UP SUBSTANTIAL ACTUAL OR POTENTIAL RIGHTS IN ORDER TO ALLOW THE STUDENT TO PARTICIPATE IN TEAM ACTIVITIES; (2) I HAVE SIGNED THIS AGREEMENT WITHOUT ANY INDUCEMENT OR ASSURANCE OF ANY NATURE, AND WITH FULL APPRECIATION OF THE RISKS INHERENT IN TEAM ACTIVITIES; (3) I HAVE NO QUESTION REGARDING THE SCOPE OR INTENT OF THIS AGREEMENT; (5) I, AS A PARENT OR LEGAL GUARDIAN, HAVE THE RIGHT AND AUTHORITY TO ENTER INTO THIS AGREEMENT, AND TO BIND MYSELF, THE STUDENT, AND ANY AND ANY OTHER FAMILY MEMBER, PERSONAL REPRESENTATIVE, ASSIGN, HEIR, TRUSTEE, OR GUARDIAN TO THE TERMS OF THIS AGREEMENT; (6) I HAVE EXPLAINED THIS AGREEMENT TO THE STUDENT, WHO UNDERSTANDS HIS/HER OBLIGATIONS.

________________________	________________________	________________________
Printed Name of Parent/Guardian	**Signature**	**Date**

As the Student, I understand and agree to all of obligations placed on me by this Agreement.

________________________	________________________	________________________
Printed Name of Student	**Signature**	**Date**

APPENDIX C

Alternative Transportation

Elk Grove Unified School District

STUDENT ALTERNATE TRANSPORTATION FORM

Students participating in off-campus District-sponsored activities, including, but not limited to, practices, games, meetings, competitions, and conferences ("Events"), are required to travel on school buses or by other District-designated methods of transportation. Under special circumstances, with the District's prior written approval, Students may be transported to and from Events (a) by a parent/guardian or other designated adult, or (2) by himself/herself. Under no circumstances may Students be transported in a vehicle driven by another student or anyone under 21 years of age.

Before the District grants a request for alternate transportation, this *Student Alternate Transportation Form* must be submitted to the School Office after it has been signed by the Student, the Student's parent/ legal guardian, and the District employee supervising the Event. Before the *Student Alternate Transportation Form* will be accepted and approved by the School Office, the individual who will transport the Student must also complete and file with the School Office an acceptable (a) *Employee and Volunteer Personal Automobile Use Form* (for parents/ guardians/designated adults), or (b) *Student Personal Automobile Use Form* (if the Student intends to drive himself/herself to Events).

If the required Forms are not submitted to and accepted by the School Office 48-hours before an Event, the Student must be transported to and from the Event through normal District-sponsored methods. A Student not complying with these provisions will not be allowed to attend or participate in the Event.

Name of Student:	
Event(s): Each approved Event or series of Events must be listed:	
Date(s):	
Reason for Request:	
Name of Designated Driver(s): Student and/or Designated Adult(s)	

I/we agree that the designated drivers and vehicles to be used are not covered under the District's automobile liability coverage. The Student, his/her parent(s)/guardian(s), and/or the driver of the vehicle are solely responsible for damage or injury to others. I/we also agree that the Student and anyone else in the vehicle assume their own risk of harm, injury or death arising from this choice for alternate transportation. The Student, his/her parent(s)/legal guardian(s), and/or the vehicle driver further agree to hold the District and its officers, employees and volunteers free from any liability arising from this alternate transportation, agreeing also to defend and indemnify them against any resulting claim.

Printed Name of Student	**Signature**	**Date**
Printed Name of Parent/Guardian	**Signature**	**Date**
Printed Name of Supervising Employee	**Signature**	**Date**

Date Received by District:	**Received/Approved by:**

THIS FORM TO BE HELD ON FILE IN THE MAIN OFFICE FOR A PERIOD OF ONE (1) YEAR FROM THE DATE OF THE CURRENT SCHOOL YEAR

Effective June 2009, Risk Management Department, 916-686-7775

APPENDIX D

Questionnaire

1. Did you run compete for Monterey Trail track and field program the previous year? Yes No
2. Have you competed at the junior varsity/varsity level in track? Yes No
3. Will this be your first year competing in a sport or being in a team environment? Yes No
4. Have you within the last 12 months had any lower extremity (leg/ankle) problems or injuries? Yes No

   Please explain:____

   ____

5. Have you had any lower extremity (leg/ankle) surgeries in the past year or last 6 months? Yes No
6. Do you have a phobia of water? Yes No
7. Have you participated on any swim teams, such as swim leagues or summer swim teams other than recreational swimming? Yes No
8. Are you comfortable residing in a water level chin deep? Yes No

APPENDIX E

Dietary and Physical Activity Log

Pre Testing Sheet

Date:______________

Name	**What did you eat within the last 24 hrs**	**What was your physical activity today**

Mid Testing Sheet

Date:_____________

Name	**What did you eat within the last 24 hrs**	**What was your physical activity today**

Post Testing Sheet

Date:______________

Name	**What did you eat within the last 24 hrs**	**What was your physical activity today**

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