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Effects of an In-season Resistance Training Program on Lower Extremity Power Output in Collegiate Basketball Players

Kevin Lee King
University of Arkansas, Fayetteville

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by

Kevin King
Southwest Baptist University
Bachelor of Science of Sports Management, 1999
Western Kentucky University
Masters of Science of Physical Education, 2003

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University of Arkansas

This dissertation is approved for recommendations to the Graduate Council.

Inza L. Fort, Ed.D.
Dissertation Director

Ro Di Brezzo, Ph.D.
Committee Member

Michelle Gray, Ph.D.
Committee Member

ABSTRACT

The purpose of this study was to evaluate changes in muscle power performance in a horizontal (forward movement), vertical, and lateral directions in collegiate basketball players due to the presence of an in-season resistance training program (ISRTP). Four basketball teams were recruited for this study. Two women's basketball teams and two men's basketball teams participated with one team in each gender participating in an ISRTP and one team not participating in an ISRTP. Fifty-three collegiate basketball players (Females= 29, Males= 24) were successfully recruited for this project. Subjects were assessed for lower extremity muscle power and muscle strength at pre-season, mid-season and post-season in order to evaluate any changes that occur over the course of a collegiate varsity basketball season. Margaria-Kalaman, single leg horizontal leap, single leg vertical leap, single leg lateral leap, 5-10-5 shuttle run, estimated RM leg press performance data were collected. Statistical analysis was performed with a multivariate analysis of variance with repeated measures. Results show that an in-season resistance training program significantly impacted the changes over the course of the season ($p < .001$) as well as a significant interaction with ISRTP and gender ($p < .001$). All six performance measurements showed significant differences between genders, and the presence of an ISRTP had a significant interaction with gender with the 5-10-5 shuttle run, single leg horizontal leap, and the estimated 1RM leg press. The results of this study support implementation of an ISRTP for male basketball players. This study did not reveal benefits of female basketball players participating in an ISRTP during a collegiate varsity basketball season. The difference in gender responses of an ISRTP on collegiate basketball players may be due to a decrease in muscular strength that was observed in male non-ISRTP basketball players, but not male ISRTP, female ISRTP, or female non-ISRTP basketball players.

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DEDICATION

I would like to dedicate this project and degree first and foremost to my personal Lord and Savior Jesus Christ. Without the grace that I have in my life because of Jesus, none of this would be possible. I would also like to dedicate this project and degree to my dad. My father is the one that planted the seed in me when I was a child that achieving this esteemed level of education is something worth pursuing, and that it was possible for me to achieve. Without his mentorship and help I would not have completed this degree. My dad was always patient and willing to help any of his children with their academic pursuits which started before kindergarten and has continued throughout our lifetimes. He continues to be a model for me in parenthood and life. He is a bastion of kindness, decency, and self-sacrifice that is becoming rarer and rarer in this world. I will continue to pattern my life after his and am proud to do so. I would, finally, like to dedicate this project to my wife and children who have given me the motivation to complete this daunting task. Without them, I don't even know if I would have tried.

TABLE OF CONTENTS

Chapter 1

INTRODUCTION

Introduction

Basketball is a time consuming sport which many colleges and universities invest a lot of effort into competing at a high level. In the National Collegiate Athletics Association (NCAA) there are 332 Division I women's teams, 290 Division II women's teams, 437 Division III women's teams representing 1,059 different institutions in the NCAA. Women's Division I, II, and III teams have 4,766, 4,287, and 6,370 participants in the respective divisions totaling 15,423 female basketball student athletes. Branching out into other governing bodies of collegiate athletics, one can add 112 Division I women's teams and 130 more Division II teams from the National Association of Intercollegiate Athletics (NAIA). The National Christian College Athletics Association (NCCAA) can add another 55 Division I teams and 30 Division II teams totaling 1,386 different women's varsity basketball programs.

Men's programs garner similar large participation numbers. In the NCAA there are 5,182 Division I participants, 4,602 Division II participants, and 7,224 Division III participants totaling 17,008 male student athletes representing 335, 389, and 414 different universities at those Division I, Division II, and Division III levels. Additional teams in the NAIA offer 113 and 131 Division I and Division II teams, respectively. The NCCAA sponsors 61 teams in their Division I ranks and 40 teams in Division II swelling the men's collegiate participation numbers to 1,383 different universities represented.

The competitive seasons for these programs often last for five full months or more with official starts that begin in mid-September and ending with national championship in post-season play in mid-March. It is also not uncommon for varsity programs to make “open gyms” available for players to come and play basketball competitively with teammates in the weeks and months before practices are officially sanctioned by their athletics program’s governing body. In addition, recreational summer leagues are utilized by some programs for an opportunity for continued player skill development with the hopes of improving athletic performance during the competitive season.

Sport skills are not the only avenue for a player to increase athletic performance. Muscular strength and muscular power have been shown to have a strong correlation with each other, and both of these attributes correlate with sport performance tests that include sprint velocity, sprint acceleration, jumping power, and agility (Peterson, Alvar, & Rhea, 2006). In addition, significantly higher values in absolute jumping power have been seen between different divisions of male basketball teams (Korkmaz & Karahan, 2006). Similar results in absolute power, as well as absolute strength, relative muscle power, and relative muscular strength have been observed in other sports (Argus, Gill, & Keogh, 2012; Garstecki, Latin, & Cuppett, 2004). Desires to compete and at the highest levels and desires to achieve success can begot a trend that covets muscular power in many sports, including basketball.

Strength and conditioning can be an integral part in preparing for peak performance during the competitive season. This applies to both on and off season regimens. Coaches often use a year round training method known as periodization to achieve peak performance for the competitive season. Periodization is a technique that strength and conditioning coaches use in order to “transfer a variety of performance variables (power, strength, or local musculature endurance) to their highest rate of development with the aim of peaking at a precise time and avoiding any stagnation, injury, and overtraining" (Hartmann, Bob, Wirth, & Schmidtbleicher, 2009, p. 1921). For collegiate basketball players, the summer and early fall semester are used for muscular power development and cardiovascular conditioning while the main goal for the competitive season is maintenance of the gains developed during the pre-season. This allows for the training of the program's student athletes to increase muscle power over the summer pre-season, building that power until the beginning of the fall competitive season. It also allows the basketball program to make these muscle power improvements and then enter a maintenance phase during the busy competitive season. Muscular power has been defined by Miriam as "the time rate of doing work" (Baechle, 1994). Despite the importance of muscle power in collegiate basketball there is a relative lack of this type of muscle power building during the regular season, which could impose a detraining effect resulting in decreases in muscle power as the season progresses and as games garner publicity and claim higher stakes both financially and competitively as teams vie for conference and national championships.

Statement of the Problem

Despite the large investment in time needed to develop game strategies, develop sport skills, as well as muscular strength and power, there are surprisingly little data on the effects of a basketball season on a player's ability to generate muscle power. In particular, there is no information on lateral movement performance in basketball players. Therefore, the research question for this study was to examine the effect of a varsity basketball season and an in-season resistance training program on horizontal (forward motion), vertical, and lateral muscle power in collegiate basketball players.

Research Hypothesis

This project had the following hypotheses:

1. There will be a decrease in each directional measure (horizontal, vertical, and lateral) of muscle power in basketball players as the season progresses.

2. The presence of an ISRTP will allow for better performance scores as the season progresses.

Definition of Terms

Muscular Strength – Muscle strength is defined by Luttgens and Hamilton as the "force a muscle or muscle group can exert against a resistance in one maximum effort" (Luttgens, & Hamilton, 1997). Muscular strength can also be defined as "the maximal force that a muscle or muscle group can generate at a specified velocity" (Baechle, 1994). In both definitions, the key component of muscular strength is the maximal effort or force that can be exerted or performed. An example in which muscular strength could be prized for a football player is with interior linemen. After the ball is snapped opposing interior linemen often meet together at the line of scrimmage in a stalemate. The player that exhibits the greater amount of muscular strength will have the ability to push the opposing player in the direction of their choosing. Another example of strength could be when men are boasting about the ability in a particular weight lifting technique (bench press, for example). In this situation, the amount of weight that a person can lift becomes the item being boasted about. The amount of time it takes, whether it is half a second, five seconds, or any time measurement is inconsequential.

Muscular Power – Muscular power is often a trait that is sought in sport. Sports will often be determined, in part, by which team or athlete can generate more velocity. Track and field runners test their speed at varying distances on a track with the winner being the athlete who was able to generate a higher velocity. Baseball and softball throwers that can generate more power have the ability to throw the ball farther and/or faster which helps pitchers strike out batters or fielders to get the ball to the correct base for outs. Conversely, batters that are able to generate more bat speed exhibit more power that allows the ball to travel farther as they try to get around the bases during competition. Football players are often praised by their ability to run away from a tackler or having the ability to chase down and tackle a ball carrier. A defensive lineman that has enough speed to get around a blocker to make a tackle or a running back that can quickly generate speed or carry tacklers as he runs are both examples of muscular power being used on the football field. Use of muscle power on the basketball court is most prominently seen when athletes attempt to propel themselves vertically. The most spectacular display of this feat is seen in a slam dunk, but vertical power is often seen in rebounding skills as well. Lateral power can easily be seen in perimeter position basketball players as they play defense. A player's defensive ability can keep an opposing player in front of them by generating speed laterally, therefore, disallowing an opposing player to drive towards the basket or create a small amount of space that could be used to execute a jump shot.

Speed and Velocity – These are terms that are often confused or used simultaneously. They are, however, two separate measures. Speed is a scalar quantity and does not measure direction, only the distance traveled in a section of time. Velocity, on the other hand, is a vector quantity that measures direction and speed (displacement). If an object is moving in a direction that is not desired it can have a great amount of speed, but little or even a negative velocity. In the case of power, velocity and not speed is used to help compute quantitative power measures (Luttgens & Hamilton, 1997).

Detraining – Detraining is "a loss of physiological adaptations and athletic performance when training is reduced or stopped completely" (Fleck, 1994). This term can be assigned to any attribute or adaptation that can occur during physical training regardless of the anatomical system that is involved. Detraining can occur in the cardiovascular system or musculoskeletal system. Detraining can manifest itself in changing levels of energy substrates or enzymatic activity (Fleck, 1994). This study concentrated on decreases in muscular power and muscular strength as it relates to muscular power.

Assumptions

1. Each field test will be performed to the best ability of the subjects.

2. Ordering of the tests allows for proper recovery of muscle energy substrates without any cross-over effects.

Limitations

1. All subjects should be rested before performing tests for this study. Although the researcher chose a time in which the subjects had at least 48 hours before and after a competition, the researcher could not control for sport practice intensities within these time frames.

2. The researcher was not able to control for the dietary intake of the subjects and therefore cannot guarantee the regularity of eating habits, alcohol, tobacco, or illegal substance use or abuse.

3. There may have been some environmental differences between teams tested despite controlling testing procedures performed. Each team performed all of their performance tests in the same environment for each of the three data points for each test.

Significance

The significance of this study lies in the ability to test the changes in muscle power capabilities in basketball players in relation to the presence of an ISRTP through a competitive season in a vertical, horizontal, and lateral direction. Applications of this study could allow strength and conditioning professionals as well as basketball coaches to better prepare their basketball teams for the rigors of a collegiate basketball season. This would include properly maintaining muscle power gains throughout the competitive season that many teams and players invest a lot of time and effort to achieve. Without an assessment of muscular power in a lateral direction, evaluation of basketball players' athletic capability is incomplete. This project will lay a foundation for the assessment of lateral muscular power that is currently absent in the evaluation of basketball athletes.

Chapter 2

REVIEW OF LITERATURE

This chapter is organized into three major sections. The first section will discuss the diference between musclular strength and muscular power, giving examples of use in sport and the general population. The second section discusses training methods used to enhance muscular power, and the third section discusses detraining.

Comparison of Muscular Strength and Muscular Power

Muscular power and muscular strength are two terms that are often confused and misused when talking about muscular performance. Sometimes, even as we evaluate muscular performance, the terms of “strength” and “power” are incorrectly interchanged. In attempts to predict muscular performance, power calculations have been used and to estimate both. Even to the point that some authors have proposed muscle power calculation to correlate higher with weight lifting activities (strength) as opposed to power lifting activities (Garhammer, 1993). With sport, there is an increased interest of exerting force at high speeds and therefore an association that attaches muscle power with speed and acceleration, but this association is not always accurate. Muscular strength is “the maximal force that a muscle or muscle group can generate at a specified velocity”, and power is “the time rate of doing work” (Baechle, 1994). Work can be defined as the amount of force that is applied multiplied by the distance that the object moves in the direction that the force is applied (Baechle, 1994; Hall, 2003). Power can be set up in an equation as follows:

Power = Work/Time (Baechler, 1994)

The components of work can be broken down and the equation can be set up as:

Power = $\frac{force\ x\ distance}{time}$ (Hall, 2003)

The formula can be manipulated further and written as:

Power = Force x $\frac{distance}{time}$ (Hall, 2003)

Since velocity is defined as distance divided by time, power is derived as:

Power = force x velocity (Hall, 2003)

It is necessary to point out that acceleration is often associated with muscle power, but the formula for acceleration is calculated by taking the change in velocity divided by the amount of time for the change. The formula for acceleration can be written as:

$\bar{A} = \frac{\Delta v}{t}$ (Luttgen,s & Hamilton, 1997)

In this equation $\bar{A}$ is equal to the average acceleration, Δv is equal to the change in velocity, and t represents the amount of time in which the change occurred. It is possible to have a positive number for acceleration, which would mean that an object is increasing in velocity or a negative number that would indicate a decrease in velocity (deceleration). Note that acceleration can change from moment to moment and that is why an average (mean) is calculated in order to get a more stable number that would be more indicative of the object's change. It is important to always remember that acceleration is a measurement of the change in velocity. As an example, compare two sprinters of equal weight and stride length and have the sprinters race over 100 meters. Because their weight (needed force production) and stride length (distance per leg movement) is set, the sprinter who accelerated faster would exhibit more power in the early phase of the race. The reason he would exhibit more power in this early portion would be because he has accelerated faster which allowed him to achieve a higher velocity at that given point in the race. If this was on a graph showing the velocity of a 100 meter sprinter during a race, a rise in velocity would be seen during the first part of the race (positive acceleration) with the goal of the remaining portion of the race to maintain the top velocity of the racer until the end of the race (zero acceleration). During the portion of the race in which the top velocity has already been achieved there is no acceleration involved because the velocity is not changing. There is, however, still power production because work is still being performed, and can be calculated by plugging in the numbers for the work (force x distance) and velocity. To illustrate this point further, a 100 meter racer will often actually have a decrease in velocity during the last portion of the race which would give him a negative number if acceleration was measured. The power production when compared to earlier in the race when the sprinter had achieved the maximum speed would be less because he is traveling at a slower velocity during the end of the race. Even though he could have a negative number in quantifying acceleration, he could still be producing a positive amount of power (still moving in the intended direction). As we relate this topic to basketball and this project, the velocity of a basketball player could be a benefit. What could be more of a benefit to the player is the ability to accelerate, decelerate, and change directions. This manifestation of power could allow offensive players to create space between themselves and a defender, therefore, creating opportunities to score. On the other side of the coin, a defender who has the ability to accelerate more than the player they are defending can provide more pressure on the offensive player, making it more difficult for the opposing player to score.

Muscular Strength and Power in Sport Populations

There have been mixed findings with the relationship of muscular strength with running performance. Some authors have shown strength to be an important factor in determining running speed and change of direction ability (Baker & Nance, 1999; Nimphius, Mcguigan, & Newton, 2010). However, others were not able to successfully correlate the two (Cronin, & Hansen, 2005). Through a meta-analysis, agreement on this subject seems precarious, especially when referencing trained athletes. However, increasing strength in order to increase sprint performance gains traction in recreationally athletic populations. The same meta-analysis showed that an approximate 23% increase in 1RM back squat strength can yield about a 2% decrease in sprint performance times as long as resistance training is performed 2-3 times per week for at least 7-13 weeks (Cronin, Ogden, Lawton, & Brughelli, 2007).

Muscular power can manifest itself differently in sport settings, but regardless of how it is measured there is often a strong correlation of these movements based on the common dependency of muscular power for results (Barnes, Schilling, Falvo, Weiss, Creasy, & Fry, 2007).

Muscular Strength and Power in the General Population

Each person uses muscle power in their everyday lives. It is used to generate velocity while walking, climbing stairs, and propelling arms to reach for objects or stand up from a seated position. With aging, one slowly loses the ability to generate muscle power, and this can affect a person's quality of life if an individual is unable to generate the muscular power needed for everyday activities. Brooks and Faulkner showed a 30% decrease in older mice when compared to adult mice. The study also showed that only one-third of the power decline was due to muscle atrophy indicating a change in neurological function of an aging individual's ability to generate muscular power (Brooks, & Falulkner, 2001). In conjunction with the Brooks and Faulkner study, a different study was conducted that showed that chair-raising ability was affected by power production and not cross-sectional area of the subjects' calf musculature (Runge, Rittweger, Russo, Schiessl, & Dieter, 2004). In order to compensate for the loss in power reduction, it has been shown that resistance training can improve muscle power performance in older men, indicating possible benefits of muscle power training for older populations (Dreyer et al., 2006). The use of moderate and high intensity resistance training can benefit older populations, and high intensity training can elicit greater gains in muscular strength than moderate intensity training (Tokmakidis, Kalapotharakos, Smilios, & Parlavantzas, 2009).

Gender Comparisons in Muscular Strength and Power

Muscle quality seems to react differently in men and women. Young women were shown to have a greater increase in muscle quality than men with resistance training while older women showed no difference with resistance training, but a significantly greater loss of muscle quality with detraining (Ivey, et al, 2000). Tanton et al. described muscle quality as "the ratio between muscle strength and size" (Tanton et al., 2009). During Tanton's 12 consecutive week training program, the authors observed that males and females adapted similarly. Muscle quality of both genders increased with resistance training meaning that the amount of strength increased even after the increases in muscle cross-sectional area was accounted for. While this study showed a larger muscle cross-sectional area increase in females with training, the authors postulated that the females in the study were less exposed to physical activity that would potentially promote strength and hypertrophy gains as part of their individual normal life style (Tanton et al., 2009).

To fully achieve the highest potential for muscle performance a multifaceted paradigm for training females is encouraged that incorporates speed, agility, and quickness (Yap, 2000).

When looking for overall lower extremity strength, males tend to have higher performance values than their female counterparts (Beutler, Motte, Marshall, Padua, & Boden, 2009; Field, 1991). The jump-ACL study even showed a strength discrepancy between the gender favoring males for strength when lower extremity strength was normalized for body mass (Beutler, Motte, Marshall, Padua, & Boden, 2009). When comparing aging differences between the genders, a similar rate of decline with age was shown in concentric strength, however women showed less eccentric strength loss over time (Lindle, et al., 1997). Lemmer et al. published an article in 1999 that compared the effects of a 9-week unilateral strength training program followed by a 31-week detraining program in older and younger men and women. Untrained (non-strength trained) subjects were recruited for this study. 1RM strength measurements for knee extension were taken before the initiation of the training program, after the 9-week strength training program was completed, at 12 weeks after completion of the strength training program (12 weeks detraining), and 31 weeks after the completion of the strength training program. Both genders and both age groups increased 1RM strength over the course of the 9-week training program. Both genders and age groups also showed significant declines in 1RM strength with 31 weeks of detraining. 1 RM strength testing showed similar increases in the younger subjects with 31 +/- 5% in young males and 39+/- 4% in young females after the training program. The older groups also showed similar performance increases when comparing genders with 27 +/- 3% and 29 +/- 4% increase in 1RM for males and females, respectively. Also, when comparing the 1RM strength differences observed at the 31-week detraining data point, there was observed a similar decrease in 1RM strength. Women and men decreased by 10% and 11% respectively over the course of the 31-week detraining time (Lemmer, et al., 2000). Upper extremity strength advantages for males have also shown to improve certain jump movements when incorporating arm swing motions (Walsch, Waters, Bohm, & Potteiger, 2007).

Neurological training tools have been advocated for female athletes for performance enhancement, injury reduction, or both (Kraemer, Duncan, & Volek, 1998; Kraemer, Hakkinen, et al., 2003; Kraemer, Mazzetti, et al., 2001; Lemmer et al., 1999; Myer, Ford, Palumbo, & Hewett, 2005). Neurological improvements may play a more important role with female athletes. Marina, Jemni, Rodriguez, and Jimenez reported a larger difference in vertical jump flight times in female gymnasts when compared to an active control group than male gymnasts when compared to an active control group (Marina, Jemni, Rodriguez, & Jimenez, 2012). When studying male and female judokas, Heitkamp, Mayer, Fleck and Horstmann found that males and females showed similar balance improvements as well as strength improvements to knee flexor and extensor muscle groups with 6 weeks of balance training. Since the balance training was not accompanied by a resistance training program and the training time was considered too small to elicit hypertrophy gains, the performance improvements were attributed to inter-muscular and intra-muscular coordination as well as increased motor unit recruitment patterns (Heitkamp, Mayer, Fleck, & Horstmann, 2002). However, vibration training incorporated into resistance training has not shown to give athletes performance enhancements beyond resistance training without a vibration modality (Fernandez-Rio, Terrados, Fernandez-Garcia, & Suman, 2010). The neurological component of lower extremity alignment has garnered attention as a potential ally in reducing female knee injuries (Hewett, Lindenfeld, Riccobene, & Noyes, 1999). Plyometric training, in particular, has elicited responses to allow lower impact landing forces and higher amount of hamstring torque which can aid in decreasing ACL injuries (Beutler, Motte, Marshall, Padua, & Boden, 2009; Hewett, Stroupe, Nance, & Noyes, 1996). By incorporating the stretch-shorten cycle into training regimens, performance gains in speed, agility, and other sport performance parameters were observed in addition to decreasing risk of knee injury (Beutler, Motte, Marshall, Padua, & Boden, 2009; Noyes, Barber-Westin, Smith, & Campbell, 2011). In-season resistance training has been endorsed for female basketball players as early as junior high school (Earles, 1989).

Mechanisms for Achieving Increased Muscular Power

Training for muscular power can be accomplished by training the body to respond with a more favorable way in regards to any of the components of the force production equation. This can be accomplished by increasing the amount of force produced, increasing the distance that was moved, or decreasing the amount of time that the force is produced or time taken to travel a specified distance (Power & Howley, 2001). A portion of the position statement from the National Strength and Conditioning Association (NSCA) states that training with “explosive exercises” could be necessary to reach the highest possible physical conditioning and defines “explosive exercises” as movements that use high rates of force production or high rates of acceleration (National Strength and Conditioning Association, 1993).

Neurological training techniques. Plyometric training has been seen to increase muscle power through neurological training of a musculotendinous unit (Potteiger et al, 1999; Walshe, Wilson, and Ettema, 1998). Decreasing the time needed to generate a velocity should also be included in a complete and well-rounded muscle power training program in order to reach peak power production (Luttgens & Hamilton, 1997; Radcliffe & Farentinos, 1999; Vissing et al, 2008). The stretch-shorten cycle, which is commonly called plyometrics, can also provide advantages in force production. By retaining elastic energy gained in a muscle through eccentric contraction, a greater concentric force can be generated (Brooks, Fahey, & Baldwin, 2005; Baechle, 1994). Walshe, Wilson, and Ettema (1998) found that eliciting an eccentric contraction after a concentric contraction produces greater force. In this study, the type of pre-force concentric contraction (eccentric or isotonic concentric) affected the amount of force produced in the subsequent concentric contraction. They found that an eccentric load significantly increased the force when compared to an isotonic force load (Walshe, Wilson, & Ettema, 1998). Hill published a study in 1950 in which he concluded that myofilaments of skeletal muscle are tension activated (as cited in Radcliffe & Farantinos, 1999). This stored elastic energy can be utilized as long as the time between the ending of the eccentric contraction and the beginning of the concentric phase (this time period has been termed the amortization phase of the stretch-shorten cycle) is short. As this amortization phase becomes longer, the muscle unit becomes less and less efficient at utilizing the stored energy (Cavagna, 1977). In addition to harnessing extra elastic energy and transforming it into kinetic energy in the desired direction of the concentric contraction, Schmidtbleicher found that there is a neurological response associated with stretch-shorten cycle training that increases neural efficiency (as cited in Radcliffe & Farantinos, 1999).

The *Journal of Applied Physiology* published an article in 2002 on the effects of "neural drive" on rate of force development following resistance training. Fifteen male subjects underwent 14 weeks of resistance training with very heavy loadings used in the final four weeks of training. Time intervals of 0-30, 0-50, 0-100, and 0-200 ms were recorded along with maximal moment of force represented by a maximal voluntary contraction to calculate rate of force development in the subjects. Isometric quadriceps contractions were performed at 70° with the subjects instructed to contract their quadriceps "as fast and forcefully as possible". EMG recordings were taken with surface electrodes attached to sites of the vastus lateralis, vastus medialis, and rectus femoris as well as the long head of the bicep femoris and semitendinosus. Results of the study showed that there was an increase in maximum isometric quadriceps contractions strength as well a steeper slope for the moment-time curve after the 14 week training period. The rate of force development increased significantly at each measuring point of time for the isometric contraction (30, 50, 100, and 200 ms) ranging in statistical significance from $p < 0.01$ to $p < 0.05$. In regards to antagonist activity in both the bicep femoris and semitendinosus, there was no observed change in EMG activity. These results demonstrate the rate of force development in part due to efferent neural drive to the quadriceps musculature (Aagard, Simonsen, Andersen, Magnusson, & Dyhre-Poulsen, 2002).

Independent of strength, Winchester et al.(2008), found that increases in muscle power can be achieved through “ballistic” training. They postulated that an increase in neural efficiency allowed for an increase in velocity of muscle contraction which produces increases in muscle power (Winchester, et al., 2008). A ballistic form of training that has proven to be effective in increasing muscle power production is weighted squat jumps. Using heavy and maximal resistive loads during squat jumps can increase muscular power outputs as well as utilizing lighter loads (Harris, Cronin, and Hopkins, 2008; Jones, 1997). The next logical question is to ask, “Which loads are better, heavy or light?”

Principle of specificity. A load of 30% 1RM has been proposed as a potential perfect load for training muscle power (Newton, and Kraemer, 1994; Wilson, Newton, Murphy, and Humphry, 1993). There seems to be no perfect answer to a single “optimal” training load in the development of muscular power (Chiu, 2008; Kawamori and Haff, 2004). The force changes acquired with resistance training seem to be specific to the velocities utilized during the training sessions (Lesmes, Costill, Coyle, and Fink, 1978). The answer to this question may be in the principle of specificity. It is sometimes referred to as the SAID principle (specific adaptation to imposed demands) and states that the body's adaptations will be specific to the demands placed on it (Baechle, 1994). For example, a weight lifter could perform a resistance exercise routine to strengthen his deltoid muscles. What the SAID principle means in this example is the deltoid muscle could become stronger, but the demands on the deltoid muscle will not translate very much into strength gains for his gastrocnemius muscles or latisimus dorsi muscles (Brooks, Fahey, & Baldwin, 2005). As this principle is applied to velocity training, the same patterns are apparent. While one can produce increases in muscular power function with heavy loads, there does not seem to be much carry-over effect to high velocity running (Harris, Cronin, & Hopkins, 2008). Conversely, training with lighter loads that allow for higher generated velocities are more likely to transpose adaptations in the force-velocity curve that better matches sport skills (Jones, 1997).

To better answer this question, McEvoy and Newton studied standard baseball training compared to ballistic resistance training (explosive movements utilizing 30%-50% 1RM) on running and throwing performance in baseball players. Results of the study showed that ballistic jump squats increased sprint performance of 27.4m (distance from home plate to first base) by 9.0% +/-3.0% as opposed to 3.1% +/- 2.7% for the control group. Bench press throws improved throwing velocities by 2.0% +/- 1.5% as opposed to a decrease in throwing velocity by a mean of -0.4% +/- 3.2%. The authors concluded the improvements were due to “velocity-specific improvements in strength, increases in rate of force development, and improved SSC (stretch-shorten cycle) performance” (McEvoy and Newton, 1998).

Increasing the distance that a force is produced can increase the measured power as well. A baseball pitcher will often be coached to hold on to the ball for a longer period of time. This would allow the pitcher a greater amount of distance to push the ball. A sprinter can be trained to lower their hips and increase the amount of hip extension in their stride to elongate a stride in order to push their body over a longer distance with each stride (Weyand, Sternlight, Belizzi, & Wright, 2000). Incorporating resisted running into training can increase velocity and measured leg power in a runner (Ross, Ratamess, Hoffman, Faigenbaum, Kang, & Chilakos, 2009). By lowering hip height in relation to the ground an athlete can increase the range of motion in which they can push in order to generate velocity or exert more force to push or pull against opposing players.

Principle of periodization. Periodization is a principle that is often employed while setting up a resistance training program. Classically, weight training volumes of repetitions and sets remained constant and it was determined that three sets of six reps was the optimal training load to gain muscle strength, power, and endurance (Atha, 1981). The oldest basic principle of periodization, called linear periodization, splits a calendar year, termed a macrocycle, into smaller sections of time, termed a mesocycle (Rhea, Ball, Phillips, & and Burkett, 2002). A minimum of two mesocycles is required to utilize training different aspects of muscle function in order to generate more force. Each mesocycle will concentrate on a different aspect of force development. The training of muscle for hypertrophy is usually the first phase or mesocycle in order to increase the cross sectional area of the muscle allowing for more muscle fiber and therefore production of more force (Willoughby, 1993). The following cycle typically works towards increasing the speed and efficiency of neural functions associated with the activation of a muscle or muscle group, therefore increasing the velocity in which the muscle is contracted

(Baechle T. R., 1994). A newer model of periodization has started to emerge called undulating periodization. This newer model utilizes microcycles that last anywhere from a couple of weeks to a couple of days in order to manipulate the amount of time being spent in a given cycle (Prestes, et al., 2009). While the first studies to utilize undulating periodization showed promise, other studies since have showed that there is little difference between an undulating and linear periodization model (Baker, Wilson, & Carlyon, 1994; Hartmann, Bob, Wirth, & Schmidtbleicher, 2009; Prestes, et al., 2009; Willoughby, 1993). Regardless of how the cycles are organized, periodization allows for the training of different components of muscle performance can be trained independently. In addition, correct analysis of muscle performance coupled with a strategic plan to enhance all of the different aspects of a muscle contraction can produce a more individualized program that is efficient and safe (Newton and Dugan, 2002).

Overload principle. In conjunction with periodization and the SAID principle, strength and conditioning coaches use a principle termed the "overload principle". Brooks, Fahey, and Baldwin (2005) describe this principle to be a "positive stressor" in which over time the body will change in order to accommodate higher demands placed upon it. The stress can be broken down into different components described by the load, repetition, rest and frequency. Load is a measure of intensity. It can be measured in the amount of resistance in a strength program or the amount of speed while conditioning cardiovascularly (Brooks, Fahey, & Baldwin, 2005). The overall trend with load is that the higher the intensity, the more recovery time will be needed before the exercise can be performed again (Brooks, Fahey, & Baldwin, 2005; Powers & Howley, 2001). The number of occurrences that a load is placed on the body is referred to as repetitions (Brooks, Fahey, & Baldwin, 2005). Repetitions are grouped together into sets to determine how many times a load is placed on the body before a rest period is given (Baechle, 1994). The amounts of repetitions and sets will vary depending on the specific goals of the resistance program (Baechle, 1994; Powers & Howley, 2001). The rest portion of the overload principle refers to the amount of time given to recover in between repetitions and/or sets as well as how much time is given to recover in between training sessions (Brooks, Fahey, & Baldwin, 2005). Frequency should work in conjunction with rest to prescribe how many training sessions are done on a weekly basis (Brooks, Fahey, & Baldwin, 2005). Some adaptations take longer to take effect than others, and so the frequency of training should provide enough time for physiological changes to occur without any detraining occurring due to a lack of training stimulus (Baechle, 1994).

Detraining

Strength training deficits were seen in adolescents with eight weeks of detraining after eight weeks of strength training consisting of two training sessions per week. A mean of 3% loss of strength was observed in the strength-trained group during their time of detraining (Faigenbaum et al., 1996). Strength has been shown to be able to be maintained with a single training session every four weeks in lumbar musculature (Tucci, Carpenter, Pollock, Graves, & Leggett, 1992). Muscle quality (referring to muscle components and architecture of muscle not related to hypertrophy) has been shown to remain intact in young populations for as long as 31 weeks (Ivey, et al., 2000). In older adults, a 12-week detraining period showed a significant decrease in strength, but overall strength was still higher than what was recorded before a 12-week resistance training regimen was initiated (Tokmakidis, Kalapotharakos, Smilios, & Parlavantzas, 2009). Similar changes in muscle cross sectional area were seen in both young (age 20-30) and older (age 65-75) adults with a longer (31 weeks) detraining period (Melnyk, Roders, & Hurley, 2009).

A group of researchers led by Mikel Ibanez Izquierdo studied the effects of four weeks of resistance either detraining or tapering of training following 16 weeks of explosive and heavy resistance training. Measurements of bench press strength and back squat strength in a Smith machine during concentric contractions in which a "maximum bar velocity" for 1RM of 60% of their "perceived" maximum was performed. Muscle power was calculated by software-fed data that was recorded by attaching a rotary encoder to the end of the bar that recorded bar positions throughout the movement and the velocity in which it moved. Lower extremity power was also calculated by evaluating unloaded vertical counter-movement jumps on a contact platform in which flight time was recorded. Total testosterone, free testosterone, cortisol, plasma GH, IGF-1, and IGF-3 were also analyzed on each testing day. Results showed significant strength increases after the 16 week training period in both the tapering and detraining groups. When comparing changes in bench press performance in the tapering and detraining groups there were significant differences ($p < 0.001$) between the two groups as the tapering group continued to increase performance (+2%) while the detraining group's performance dropped (-9%). In regards to back squat muscle power performance, a significant difference was observed here as well. The tapering group was able to increase bench press power (+3%) as the detraining group's performance declined (-17%) with strength differences of +3% and -6% respectively for the tapering and detraining groups ($p < 0.001$). CMJ showed a significant advantage with the tapering group ($p < 0.01$) with unchanging mean values in the tapering group and a deterioration of performance in the detraining group (-3%). There were no significant differences in any groups at any of the testing times for any of the tested hormones (Izquierdo, et al., 2007).

Sport in-season training was studied with 16 team handball players who underwent 12 weeks of in-season resistance training followed by seven weeks of in-season detraining. Team handball players were tested for sprint performance over 30 meters in which times were recorded at the 15-meter mark and 30-meter mark. Vertical jump height, weighted vertical jump height of 20 and 40 kg, maximal dynamic strength of the bench press and parallel squat movements, and a maximum velocity throw of a standard handball were measured. Results showed that there were significant performance increases throughout the 12 week resistance training session with an exception at the 15-30 meters marks between the 2^{nd} and 3^{rd} testing times. Vertical jump height showed significant gains throughout the resistance training time period in the countermovement jump, as well as the 20 kg and 40 kg weighted countermovement jumps. Strength measures showed improvements in the 1RM bench press at the 6-week and 12-week points in the resistance training program with improvements of 16% and 10%, respectively, and an overall increase of 27.7%. Increases in the 4RM parallel squat showed improvements of 30.7% over the first 6-weeks of resistance training, 9.7% over the second 6 week training cycle for a total improvement of 43%. After the 7-week detraining period had elapsed and the athletes were retested for CMJ and ball throw velocity, there was not a statistically significant loss in CMJ, but there was in ball throw velocity ($p < 0.05$) (Marques, & Gonzalez-Badillo, 2006).

An in-season study was conducted on adolescent male basketball players in which a detraining and a reduced training program were compared at weeks 4, 8, 12, and 16 following a 10 week “complex” training program that included resistance training and plyometrics. Measurements taken at each of the 5 data points included a squat jump, countermovement jump, depth jump, mechanical power, and medicine ball throw. Results of this study indicated that there were no statistically significant differences between the reduced training group and the detraining group in any of the measurements taken (Santos & Janeira, 2009).

Little research has been published about the actual effects on power performance as a collegiate basketball season progresses. Loss of strength in both starters and non-starters over a two year span was observed in a NCAA Division I men's basketball team, but muscle power was not evaluated in that particular study (Caterisano, Patrick, Edenfield, and Batson, 1997). A study was published in 1998 that took measurements on a collegiate football team. Data was collected for both strength and power measurements. Pre-season measurements were taken for bench press, standing long jump, vertical jump, 20-yard shuttle run, and sit-and-reach flexibility test. Sixteen weeks later after the season had ended, the measures were repeated. The results showed that there was a significant decrease in performance for the bench press and flexibility in all players as well as a significant decrease in the vertical leap ability of the non-linemen that were tested (Schneider, Arnold, Martin, Bell, & Crocker, 1998). While this study provides good information on muscle power and strength performance ability changes during a collegiate football season, there is still a void in the literature that narrows the possible time table of when the decreases in muscle performance occurs throughout a competitive season.

Hoffman, Fry, Howard, Maresh, and Kraemer (1991) evaluated nine male division I basketball players for strength, speed, and endurance. Measurements taken were body weight, skin fold measurements, bench press strength, squat strength, 27-meter sprint speed, vertical leap, 1.5 mile run time, T-test (agility), and thigh girth before pre-season workout (including weightlifting regimen), before the competitive season, mid-season, and post-season. Results showed a significant decrease in mid-season squat strength, sprint speed, and vertical leaping ability as well as a decrease in post-season sprint speed when compared to pre-competitive season measurements (Hoffman, Fry, Howard, Maresh, & Kraemer, 1991).

In 2005, Andersen et al. found that after three months of resistance training and three months of subsequent detraining, isokinetic muscle strength and power at 30°/s and 240°/s. There was also a decrease from pre-training levels of EMG activity of agonist muscle at 30°/s. While these findings are well in line with other studies conducted on detraining, Andersen found that there was an increase of 14% in peak velocity of unloaded knee extension with the peak occurring at an increased (extended) knee joint angle. While this finding of increased velocity with detraining can be viewed as contradictory, it should be noted that the strength program for this study did not include training sessions in which muscle power was emphasized. It should also be noted that this increase in power with detraining would only be pertinent to high-velocity unloaded movements such as kicking as soccer ball or punching and not loaded movements that would include jumping and running that would be commonly seen in basketball (Andersen et al, 2005).

Kraemer et al. found in their study published in 2002 on recreationally resistance trained men that muscle power deteriorated more than muscle strength with six weeks of detraining without any significant changes in hormonal levels. In this study examining elbow and knee extensors and flexors, only peak elbow flexion strength was significantly different ($p < 0.05$) with six weeks of detraining while there was no significant strength differences with three weeks of detraining (Kraemer et al., 2002).

Summary of the Literature

Muscle power is different than strength in that there is a time component involved with muscle power. Muscle power is used by everyone in their daily tasks for living, but is a critical component for basketball players during competitions. A lot of time, effort, and planning are used in order to train basketball players to perform optimally for competition. The use of periodization and the overload principle are used to increase an athlete's ability to generate force while ballistic movements are used to neurologically train musculature to contract at higher speeds, therefore creating more muscle power. Due to constraints in schedule and a shift of emphasis to sport skill development, muscle power can suffer from a detraining effect throughout a competitive basketball season. More research is needed to understand the time frame of when the detraining occurs throughout the season needs. In particular, there is no known data known to this author of in-season power measurements evaluating lateral movements in basketball players, nor is there a clear protocol available to evaluate muscle power in the frontal plane.

Chapter 3

METHODOLOGY

The purpose of this study was to evaluate muscle power performance capabilities of collegiate basketball players during their competitive season. A repeated measures design was used for this study. Approval from the Institutional Review Board from the University of Arkansas and Evangel University's Research Review Board was obtained. All athletes were informed of the risks/benefits of this study as well as time requirements. Each individual was assigned a code number for the duration of the testing. The code was destroyed upon completion of this project to ensure anonymity of each individual's test scores. Coaching staff had access to scores of individuals from their respective teams only for the purpose of evaluating their own programs. Each athlete signed a consent form and was given the option to not participate in this research project or to withdraw at any time.

Subjects

Fifty-five varsity collegiate basketball players were recruited for this project from three different collegiate varsity basketball programs. Two men's and two women's teams were recruited for this study. Height, weight, playing position, standing vertical reach height, single leg vertical leap height, Margaria-Kalaman test, single leg lateral leap, single leg horizontal leap, three-site skin fold measurements for calculating body density and body fat percentage, five repetition leg press max, and pro agility shuttle run scores were recorded for each subject participating in this project. Each subject has acted as their own control group and was tested the week before initiation of their varsity competitive season, as close to the mid-point in their respective seasons that allowed a 48-hour window for testing both before and after a competition, and within 10 days following the conclusion of their respective competitive seasons.

Testing Procedures and Instuments

Warm-up. Each subject performed their respective team's normal warm-up routine prior to any testing in order to maintain consistency for the subjects. In the event that a team did not have a specified warm-up, the following protocol was performed before testing began.

General warm up at a medium intensity for five minutes

Each of the following movements performed for the width of the basketball court:

High knees

Butt kicks

Tin soldiers

Carioca

Lateral slides

Walking lunges

Single leg vertical countermovement leap test. The standing reach height of each subject was measured by instructing the subject to stand with their feet flat on the ground and reach as high as he or she could with one arm outstretched over their head. The highest slat that the student/athlete could displace from the Vertec jump-testing device (Sports Imports, Columbus, OH) while maintaining a flat-footed stance was recorded to the nearest half inch. From a static standing position, the subject was asked to perform a countermovement vertical jump on their preferred leg reaching as high as he or she could displacing the highest slat possible on the Vertec jump testing device. Each subject was allowed three attempts, and the best of the three scores was recorded. The difference between the standing reach score and the countermovement vertical jump score was calculated and recorded as the subject's vertical jump score. Subjects who attempted to take a step(s) in order to gain momentum before initiation of the counter jump movement were asked to repeat that particular attempt. The two-legged version of this test has been shown to examine lower leg power with a reliability score of .93, validity score of .78, and an objectivity coefficient scoring greater than .90. A benefit of this test is that very little technique in involved in performance (Miller, 2002). While a single leg vertical leap test could entail more technique for balance, it has previously been shown to have a statistically significant correlation with the single leg horizontal and lateral countermovement leap tests in both men and women at a $p \leq .05$ level and a $p \leq .01$ level in both men and women performing a single-leg lateral countermovement leap, and in men performing a single leg countermovement lateral leap (Meylan et al., 2009).

Single leg horizontal countermovement leap test. The subject started at a designated starting line. Using the dominant leg, the subject lowered themselves into a small squat and jumped forward as far as possible with their hands placed on their hips. The subject was instructed to land on the same leg from which the jump was initiated. The distance recorded is based upon where the heel of the subject lands. After being allowed an orientation, each subject was allowed three attempts. The best of the three scores were recorded. This field test has been reported to have a correlation coefficient with the single-leg lateral jump with men and women to be .638 and .605 and .640 and .659 for men and women in the single-leg vertical jump (Meylan et al., 2009).

Single Leg Vertical Leap

a.

b.

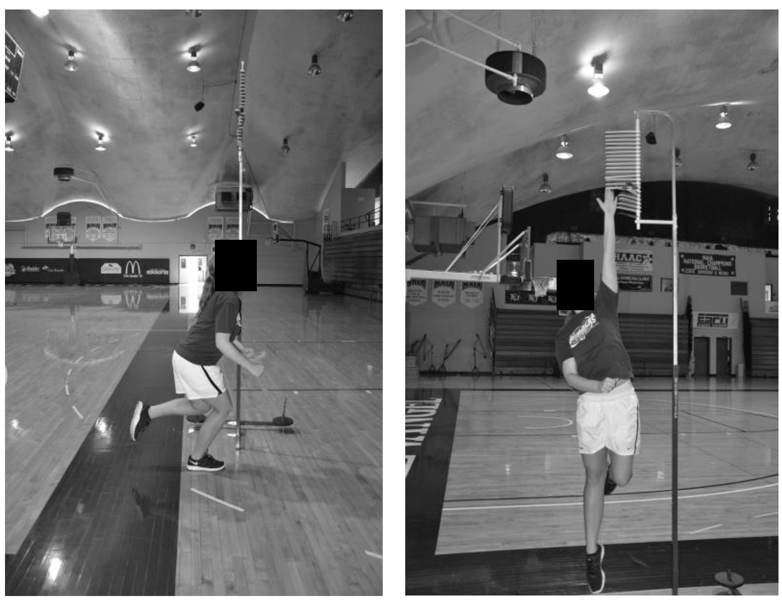

Figure 1. Standing single leg reach assessment (a) and single leg vertical leap measurement (b). Photo by author.

Single Leg Horizontal Leap

a.

b.

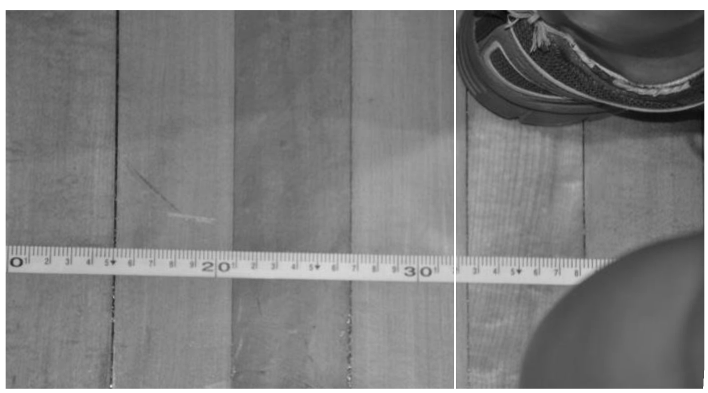

Figure 2. Starting and landing position for single leg horizontal leap (a). Proper measurement of landing horizontal leap scored utilizing the hindmost component of the foot closest to the start line (b). Photo by author.

Single leg lateral countermovement jump. The subject starts with the inside of their dominant leg on the edge of a designated starting line. The subject performs a countermovement and jump laterally with hands placed on their hips. The subject is asked to land on the jumping leg. The measurement is taken on the medial border of the foot of the non-dominant leg. After being allowed an orientation, each subject was allowed three attempts. The best of the three scores was recorded. This field test has been reported to have a correlation coefficient with the single-leg horizontal jump for men and women to be 0.638 and 0.605 with coefficients of 0.596 and 0.364 for men and women performing the single-leg vertical jump (Meylan, et al., 2009).

Margaria-Kalamen power test. The Margaria-Kalamen Stair-climbing Test was performed on stairs. From a 6-meter running start, subjects were instructed to sprint up the stair steps as fast as possible, with foot placement only on the third, sixth, and ninth steps. The time from the 3rd step to the 9th step was recorded. The test was performed three times with 2-3 minutes of rest between each of the subject's repetitions. Power (in Watts) is calculated from the following formula:

$$P = (M \times D) \times 9.8/t$$

In which:
P = Power (Watts)
M = Body mass (kg)
D = Vertical distance (m)
t = Time (s)

The amount of time required to perform the Margaria-Kalamen Power Test was measured with a wireless digital timing system (Brower Timing Systems, Draper, UT).

Single Leg Lateral Countermovement Jump

a.

b.

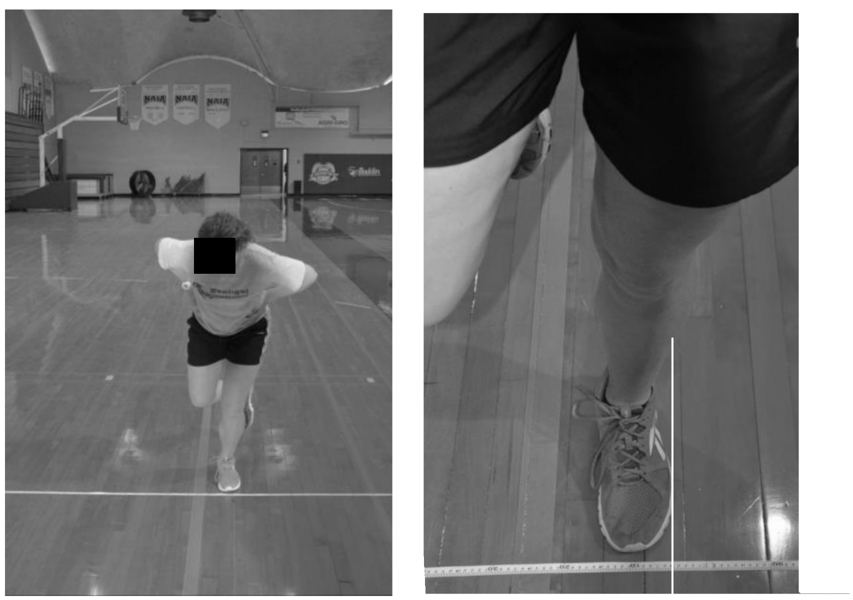

Figure 3. Starting position for single leg lateral leap (a). Landing position and proper measurement of landing lateral leap scored utilizing the lateral border of the foot (b). Photo by author.

Skin-fold measurements. Three sites for skin-fold measurements were chosen, and measured based on the subject's gender using the Jackson and Pollock percent body fat technique. Females had skin-fold measurements taken at triceps brachii, suprailium, and abdominal sites. Males had skin-fold measurements taken at the chest, triceps brachii, and subscapular sites. The sum of the respective sites were calculated and entered into a formula to calculate body density. The formulas are provided below in which X= sum of skinfolds and Y= age of the subject. Each site was measured twice to insure reliability.

Women: Body Density=1.089733-0.0009245(X) + 0.0000025$(X)^2$ – 0.0000979(Y)

Men: Body Density=1.1125025 – 0.0013125(X) + 0.0000055$(X)^2$ -0.0002440(Y)

Once the body density was calculated, the percent of body fat was then calculated with the following formula:

% Body Fat = (495/ body density) – 450

5-10-5 shuttle (pro agility) test. Three lines were marked or taped on the testing floor in increments of five yards (10 yards end to end with a line at the half-way point). Each subject was asked to stand in a two-point stance straddling the start/finish line. The subject was instructed to sprint to the right for five yards and touch a marked line on the floor with their right hand. The subject then immediately sprinted to the left for ten yards and touched the line on the opposing end of the course with their left hand, and then immediately sprinted through the start/finish line located in the middle of the course. The course was timed with an electronic timer using a pressure pad for start timing and a laser trip line to stop timing of the subjects.

5-10-5 Shuttle (Pro Agility) Test

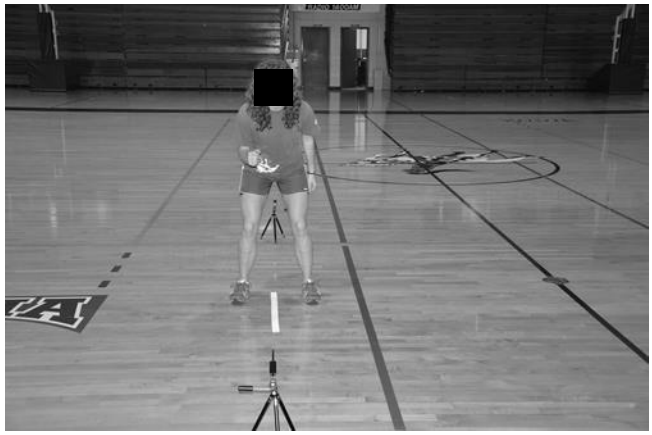

Figure 4. Starting position for 5-10-5 Shuttle (Pro Agility) Test. Photo by author.

Estimated maximum strength testing. Subjects were asked to perform a maximum leg press lift to estimate leg strength. In addition to the team warm-up performed at the beginning of the testing session, each subject was asked to perform one set of 12 repetitions of a back squat at a self-selected medium intensity. Each subject was asked to choose a weight that they thought they could leg press for a maximum of five repetitions. In the event that a subject did not think they would be able to accurately estimate how much weight they can lift for five repetitions, the researcher aided them in establishing an appropriate weight. Each subject had an opportunity to attempt the selected weight and rate the weight as "light, medium, heavy, or very heavy". Adjustments to the weight were made to the load until a "very heavy" rating was attained. The weight and the actual number of performed repetitions was recorded and the one-repetition estimated maximum lift was calculated and recorded. Dan Wathan's estimated maximum strength formula was chosen due to its accuracy in estimating leg strength with the back squat. The correlation coefficient between the Wathan's estimated formula and the actual performed maximum lift for the back squat was .992 with a mean of 0.02% difference between the strength measures (LaSuer, et al., 1997). The formula used to calculate the one repetition maximum was:

$1RM = 100 \times \text{weight lifted}/ 48.8 + 53.8 \times e^{-0.075 \times \text{repetitions performed}}$ (LaSuer, 1997)

Presence of an ISRTP. Both teams that participated in an ISRTP performed resistance training approximately once a week while maintaining practice and game schedules. Both teams performed lower extremity resistance training that utilized both single and multi-joint lifting exercises. Both teams also chose similar resistance exercises as well as prescribed similar repetitions and sets for their respective training sessions. The total amount of training sessions as well as the timing of day and week of the training sessions did vary between the two teams.

Both teams attempted to perform ISRTP approximately once a week with at least two days between resistance training and game competition as game schedule allowed.

Estimated Maximum Strength Testing

a.

b.

Figure 5. Starting position and proper foot placement for Estimated Maximal Strength Test (a). Proper depth at minimum of 90° of knee and hip flexion (b). Photo by author.

Data Analysis

Statistical Tools. This study was conducted in order to determine the effects of a basketball season on the ability of basketball players to generate muscular power, which was analyzed with a multivariate analysis of variance using SPSS version 20 software. Repeated measures MANOVA on the Margaria-Kalaman, 5-10-5 shuttle run, single leg vertical leap, single leg horizontal leap, single leg lateral leap, and estimated 1RM leg press was used in order to more accurately describe trends in muscle power through the course of the basketball season. Categories of gender and the presence of an ISRTP were identified as fixed factors for the statistical analysis. This type of statistical analysis allows for an assumption of linear change between the data points. Data points for pre-season and post-season were used for assessment of the entire season. The mid-season data point was compared to the pre-season data point to evaluate change in muscular power and strength in the first half of the season. Similarly, comparison of the mid-season data point and the post-season data point was utilized for assessment of muscle power and strength change in the second half of the season.

Chapter 4

RESULTS

The four different basketball teams consisting of two men's and two women's teams were all traditional aged college students. Table 1 shows mean anthropometric scores for the subject's age, height, weight, and body fat percentage. Muscle power in a horizontal (forward) direction was assessed using the single leg horizontal leap. Muscle power in a vertical direction was assessed using single-leg vertical leap scores and the Margaria-Kalaman test. Muscle power in a lateral direction was tested with the single-leg lateral leap test. The 5-10-5 shuttle run is a multidirectional test, and the estimated 1RM leg press evaluated the tensile strength component of muscular power.

When examining the length of time encompassing the entire basketball season the multivariate analysis revealed that there was a significant difference between genders ($p < .001$), the presence of an in-season resistance program ($p < .001$), and the interaction between gender and the presence of an in-season resistance training program ($p < .001$), according to the Wilks' Lambda multivariate test. The same three factors were significant in both the first and second half of the season. Statistical results comparisons of the pre-season and mid-season, mid-season and post-season, and pre-season and post-season are available below (Table 2). Repeated measures analyses of the individual tests are examined below.

Margaria-Kalaman

There were no significant differences in the Margaria-Kalaman scores over the entire course of the season. There also were no significant differences in watts production over the first

Table 1

Anthropometric Descriptive Data for Collegiate Basketball Players

Measurement	Male	Female
Weight	82.6 ± 8.2	71.5 ± 9.3
Height	184.8 ± 7.9	177.7 ± 6.4
Age	19.3 ± 1.4	19.8 ± 1.4
N	24	30

Note. Mean and standard deviations for weight, height, and ages of the participants.

Table 2

P. Values for Wilk's λ

	Pre-Mid		Mid-Post		Pre-Post	
	λ	P. Value	λ	P. Value	λ	P. Value
ISRTP	.367	.001	.384	.001	.212	.000
Gender	.513	.018	.131	.000	.196	.000
Gender*IRSTP	.319	.000	.495	.010	.244	.000

Note. IRSTP = in-season resistance training program half of the season as well as the second half of the competitive basketball season. Between-subjects examination showed that there were no statistically significant differences with the presence of an in-season resistance training program or a significant interaction between gender and the presence of an in-season resistance training program. However, there was a significant difference between genders ($p < .001$). Overall, the female Margaria-Kalaman watts scores were significantly lower than the males. See Table 3 for the mean Margaria-Kalaman watts scores for preseason, midseason, and postseason. Graphical representation is presented in Figure 6.

Single Leg Vertical Leap

During season, vertical power measured by the single leg vertical leap decreased with significant differences between the pre-season and post-season scores ($p = .005$) and between the mid-season and post-season scores ($p =.024$). There was not a significantly statistical difference between the pre-season and mid-season scores ($p =.338$). Overall, there was a significant gender difference ($p < .001$) in that males scored higher single leg vertical leap scores than females. There was not a statistically significant difference between the groups that participated in an in-season resistance training program ($p = .212$), nor was there significant interaction between gender and the presence of an in-resistance training program ($p = .317$). See Table 4 for the mean vertical measurements for preseason, midseason, and postseason single leg vertical leap scores. The trend in power production change should be noted in the male subjects that did not participate in an in-season resistance training program. This group showed a decrease in performance between the mid-season and post-season testing times (Figure 7).

Table 3

Margaria-Kalaman

Variable	Male			Female			Total		
	Pre	Mid	Post	Pre	Mid	Post	Pre	Mid	Post
Non-IRSTP									
N	7	7	7	10	10	10	17	17	17
Mean (W)	3446	2710	3108	1947	1972	1939	2564	2275	2421
ISRTP									
N	9	9	9	6	6	6	15	15	15
Mean (W)	2766	3311	3299	1878	2069	1988	2411	2814	2775
Total									
N	16	16	16	16	16	16	32	32	32
Mean (W)	3063	3048	3216	1921	2008	1958	2493	2528	2586

Note. ISRTP = in-season resistance training program; N = total number of participants; W = watts; Pre = preseason; Mid = midseason; Post = postseason. p values comparing the three data points were: preseason to midseason $p = .901$; midseason to postseason $p = .120$; preseason to postseason $p = .081$.

Margaria-Kalaman Scores for Males and Females With and Without the Presence of ISRTP

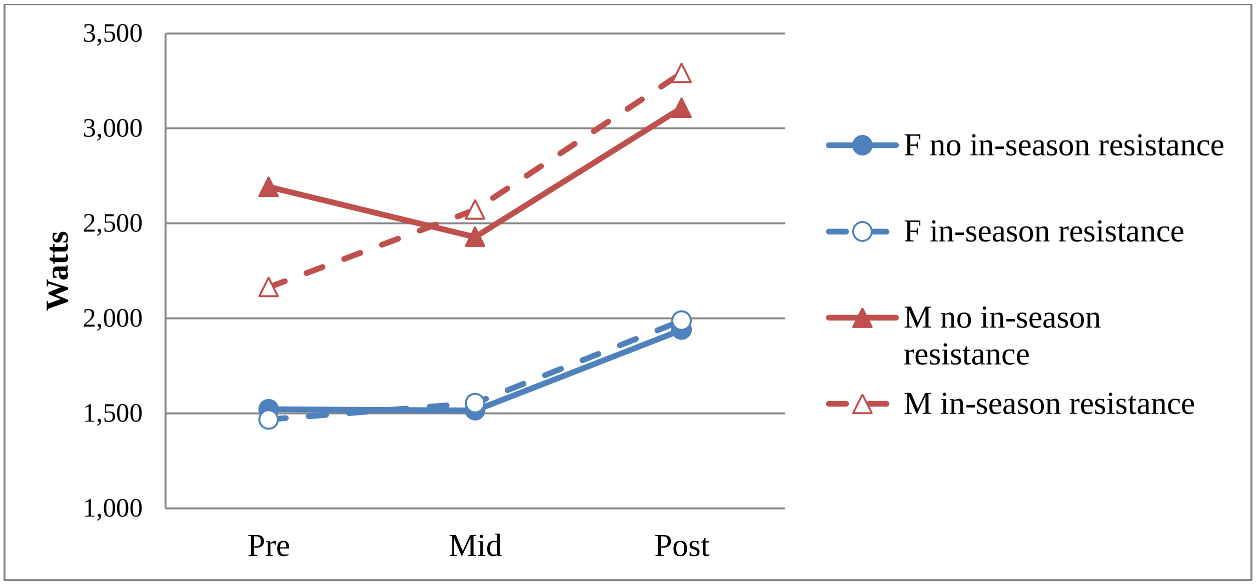

Figure 6. Mean Margaria-Kalaman scores by presence of an in-season resistance program and gender at Pre-, Mid-, and Post-season.

Table 4

Single Leg Vertical Leap

	Male			Female			Total		
Variable	Pre	Mid	Post	Pre	Mid	Post	Pre	Mid	Post
Non-IRSTP									
N	8	8	8	10	10	10	18	18	18
Mean (in.)	22.87	22.12	16.81	14.80	14.55	15.60	18.38	17.91	16.13
ISRTP									
N	9	9	9	8	8	8	17	17	17
Mean (in.)	18.44	19.33	19.44	15.18	14.00	15.25	16.91	16.82	17.47
Total									
N	17	17	17	18	18	18	35	35	35
Mean (in.)	20.52	20.64	18.20	14.97	14.30	15.44	17.61	17.38	16.78

Note. ISRTP = in-season resistance training program; N = total number of participants; in. = inches; Pre = preseason; Mid = midseason; Post = postseason. P values comparing the three data points were: preseason to midseason p = .338; midseason to postseason p = .024; preseason to postseason p = .005.

Single Vertical Leap Scores for Males and Females With and Without the Presence of ISRTP

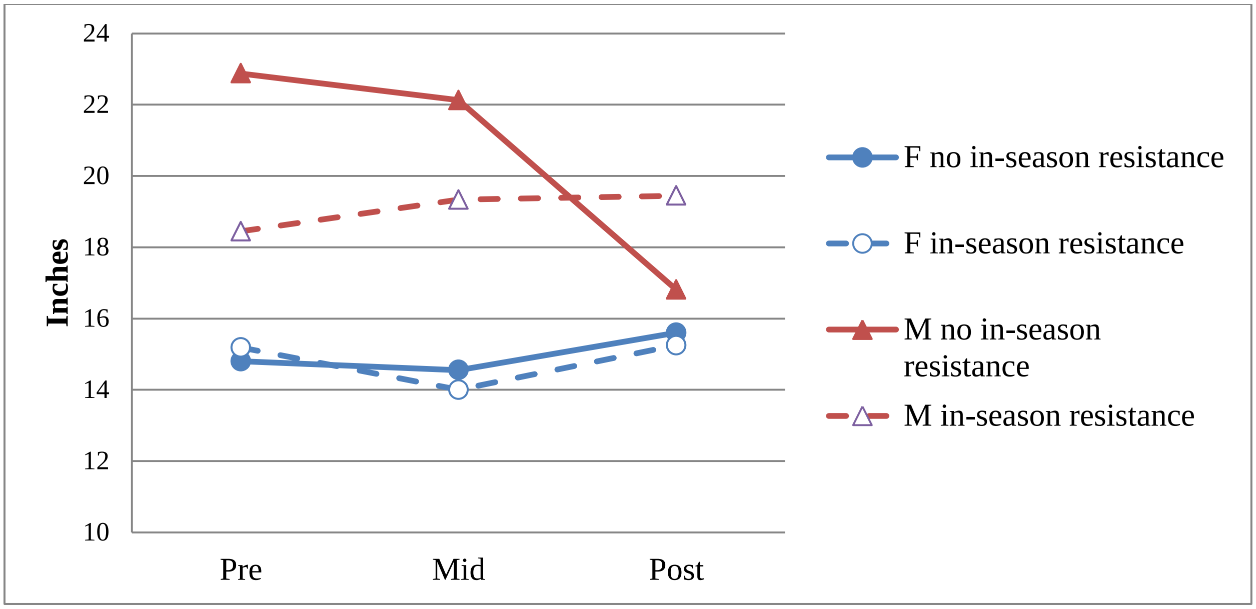

Figure 7. Mean Single Leg Vertical Leap scores for males by presence of an in-season resistance program at Pre, Mid, and Post-Season.

5-10-5 Shuttle Run

Overall there was an observed significant gender difference ($p < .001$), which is represented in Figure 8. Female time scores were slower than male time scores. There was not a significant difference between the groups that did or did not involve an in-season resistance training program, but when combined with gender, a significant interaction was detected ($p = .008$). Females in the resistance training group were slower than their counterparts in the non-resistance trained group while the opposite was true for the males (Figure 8). Shuttle times mean results are represented in Table 5.

Single-Leg Lateral Leap

Overall only gender was significant when looking at different groups within the study sample ($p < .001$) with males scoring higher than females. Means for post, mid, and in-season are presented in Table 6. Graphical representation of mean scores are represented in Figure 9.

5-10-5 Shuttle Run Scores for Males and Females With and Without the Presence of ISRTP

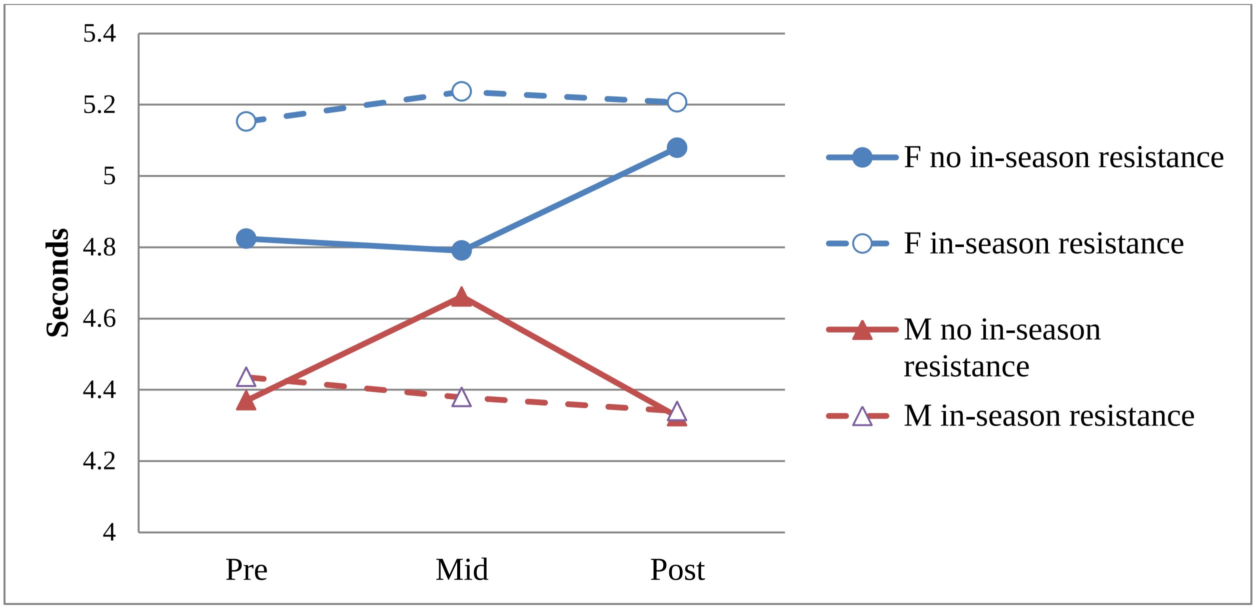

Figure 8. Mean 5-10-5 shuttle run scores by presence of an in-season resistance program and gender at Pre, Mid, and Post-season.

Table 5

Shuttle Run

	Male			Female			Total		
Variable	Pre	Mid	Post	Pre	Mid	Post	Pre	Mid	Post
Non-IRSTP									
N	8	8	8	10	10	10	18	18	18
Mean (sec.)	4.37	4.66	4.32	4.82	4.79	5.07	4.62	4.73	4.74
ISRTP									
N	9	9	9	8	8	8	17	17	17
Mean (sec.)	4.43	4.37	4.34	5.15	5.23	5.20	4.77	4.78	4.74
Total									
N	17	17	17	18	18	18	35	35	35
Mean (sec.)	4.40	4.51	4.33	4.97	4.98	5.13	4.69	4.75	4.74

Note. ISRTP = in-season resistance training program; N = total number of participants; sec. = seconds; Pre = preseason; Mid = midseason; Post = postseason. P values comparing the three data points were: preseason to midseason p = .108; midseason to postseason p = .551; preseason to postseason p = .204.

Table 6

Single Leg Lateral Leap

	Male			Female			Total		
Variable	Pre	Mid	Post	Pre	Mid	Post	Pre	Mid	Post
Non-IRSTP									
N	8	8	8	10	10	10	18	18	18
Mean (in.)	2.10	2.03	2.10	1.75	1.77	1.74	1.91	1.89	1.90
ISRTP									
N	10	10	10	8	8	8	18	18	18
Mean (in.)	2.04	2.07	2.03	1.75	1.71	1.63	1.91	1.91	1.85
Total									
N	18	18	18	18	18	18	36	36	36
Mean (in.)	2.07	2.05	2.06	1.75	1.75	1.69	1.91	1.90	1.88

Note. ISRTP = in season resistance training program; N = total number of participants; in. = inches; Pre = preseason; Mid = midseason; Post = postseason. P values comparing the three data points were: preseason to midseason p = .633; midseason to postseason p = .264; preseason to postseason p = .165.

Single Leg Lateral Leap Scores for Males and Females With or Without an ISRTP

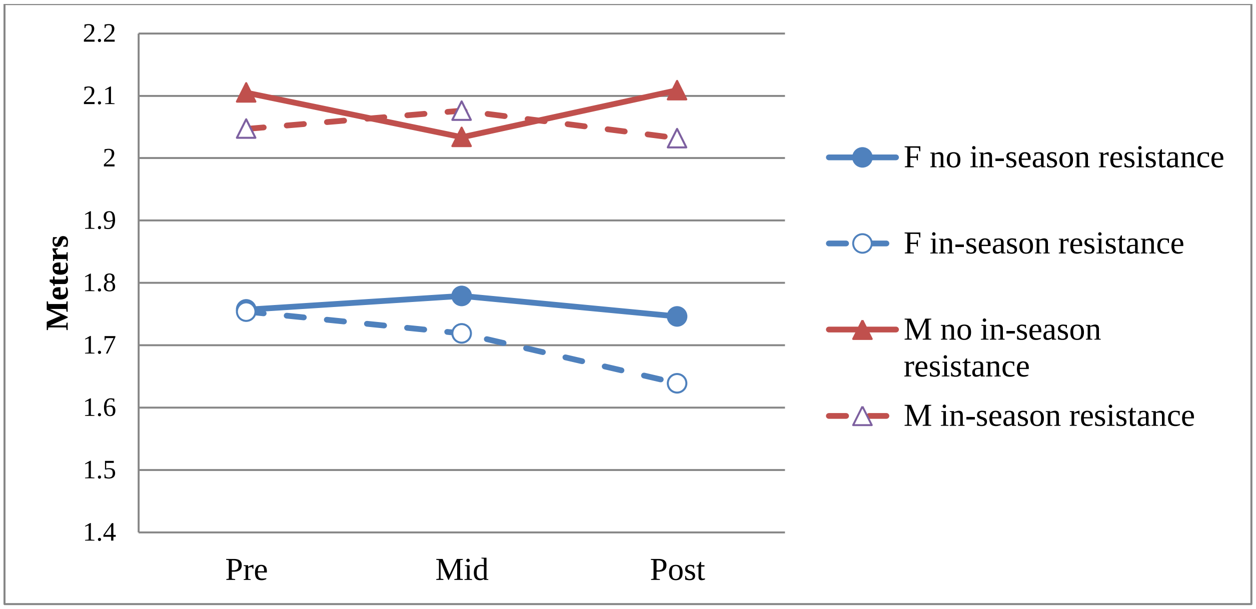

Figure 9. Mean Single Leg Lateral Leap scores for males by presence of an in-season resistance training program at Pre-, Mid-, and Post-season.

Single Leg Horizontal Leap

With regard to horizontal power, there was an overall significant decrease from mid-season to post-season ($p = .011$) mean horizontal leap scores. There was also a significant difference between genders ($p < .001$) with male scores higher than their female counterparts. Testing score means are presented in Table 7. In addition, there was also significant interaction between gender and the presence of an in-season resistance training program ($p = .015$). In the non-resistance trained group, the males decreased in lateral leap performance at the mid-season mark while the resistance trained male group showed a slight increase (Figure 10).

Estimated 1RM Leg Press

In the estimated 1RM leg press, males significantly scored higher than females ($p < .001$), particularly with presence of an in-season resistance training program ($p = .004$). Means displaying gender difference with or without the presence of an in-season resistance training program are represented in Figure 11. The presence of an in-season resistance program produced higher mean leg press scores compared to the means of subjects that did not participate in a resistance program. Mean scores for males and females with or without an in-season resistance training program are represented in Table 8.

Percent Body Fat

Changes in body fat percentage were not statistically significant over the course of the season or between any combinations of two data points. Body fat percentages are presented in Table 9. Using change in percent body fat as a covariate did not provide a more accurate statistical model for changes in muscular power over the course of the competitive season.

Table 7

Single Leg Horizontal Leap

	Male			Female			Total		
Variable	Pre	Mid	Post	Pre	Mid	Post	Pre	Mid	Post
Non-IRSTP									
N	8	8	8	10	10	10	18	18	18
Mean (in.)	2.24	2.11	2.24	1.79	1.92	1.78	1.99	2.00	1.99
ISRTP									
N	10	10	10	8	8	8	18	18	18
Mean (in.)	2.26	2.29	2.23	1.69	1.75	1.60	2.01	2.05	1.95
Total									
N	18	18	18	18	18	18	36	36	36
Mean (in.)	2.25	2.21	2.24	1.74	1.84	1.70	2.00	2.03	1.97

Note. ISRTP = in-season resistance training program; N = total number of participants; in. = inches; Pre = preseason; Mid = midseason; Post = postseason. p values comparing the three data points were: preseason to midseason p = .253; midseason to postseason p = .011; preseason to postseason p = .060.

Single Leg Horizontal Leap Scores for Males and Females With or Without an ISRTP

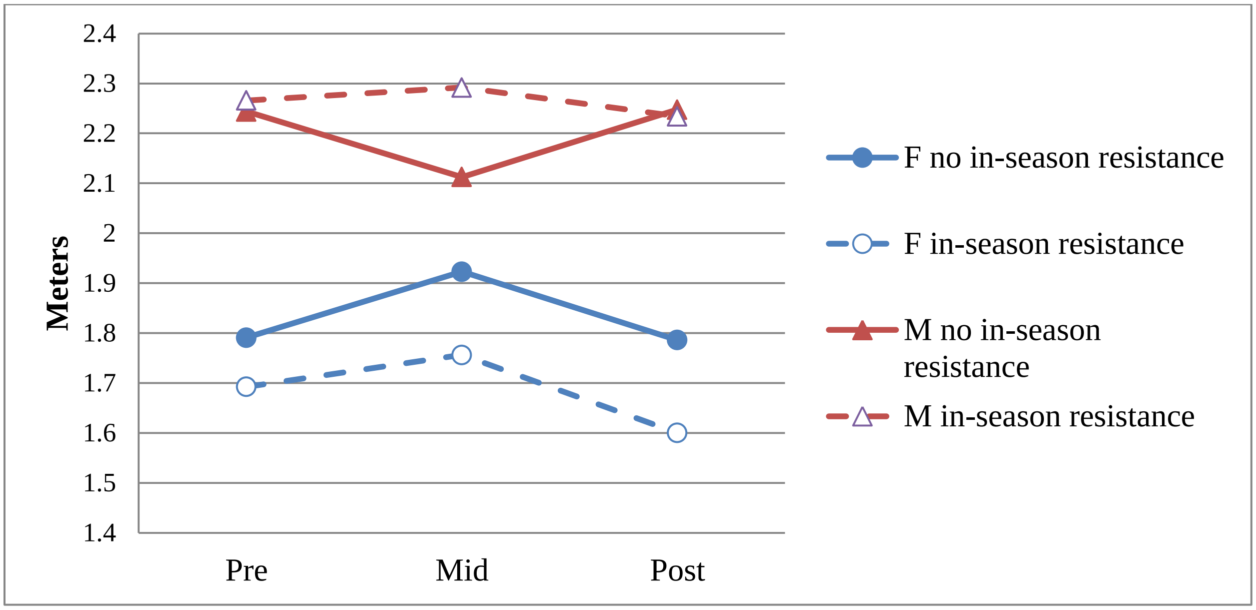

Figure 10. Mean estimated lateral leap scores by presence of an in-season resistance training program at Pre-, Mid-, and Post-season.

Estimated 1RM Leg Press Scores for Males and Females With or Without an ISRTP

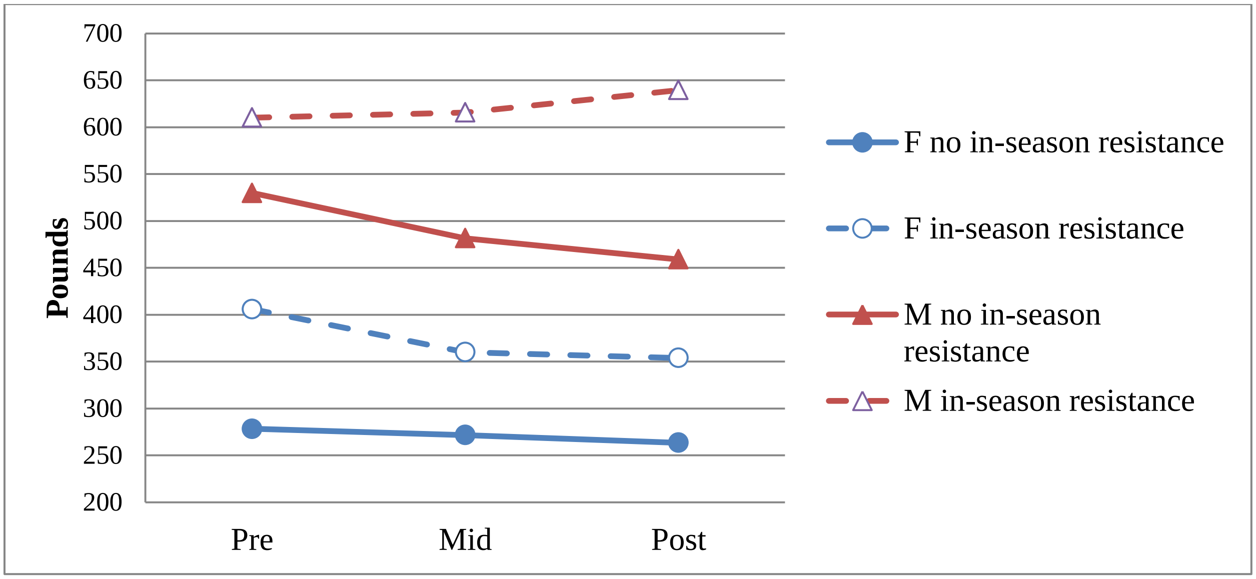

Figure 11. Mean Estimated 1RM max leg press scores by presence of an in-season resistance training program at Pre-, Mid-, and Post-season.

Table 8

Estimated Leg Press Max

Variable	Male			Female			Total		
	Pre	Mid	Post	Pre	Mid	Post	Pre	Mid	Post
Non-IRSTP									
N	7	7	7	9	9	9	16	16	16
Mean (lbs)	529.9	481.7	459.0	278.5	271.7	263.5	388.5	363.5	349.1
ISRTP									
N	10	10	10	6	6	6	16	16	16
Mean (lbs)	610.3	615.6	639.6	406.1	360.0	354.0	533.7	519.8	532.5
Total									
N	17	17	17	15	15	15	32	32	32
Mean (lbs)	577.2	560.4	565.2	329.5	307.0	299.7	461.1	441.7	440.8

Note. ISRTP = in-season resistance training program; N = total number of participants; lbs = pounds; Pre = preseason; Mid = midseason; Post = postseason. P values comparing the three data points were: preseason to midseason $p = .195$; midseason to postseason $p = .729$; preseason to postseason $p = .186$.

Table 9

% Body Fat

Variable	Male			Female			Total		
	Pre	Mid	Post	Pre	Mid	Post	Pre	Mid	Post
Non-IRSTP									
N	7	7	7	9	9	9	16	16	16
Mean (in.)	5.56	7.59	7.55	18.67	18.52	18.76	12.93	13.73	13.85
ISRTP									
N	10	10	10	6	6	6	16	16	16
Mean (in.)	7.28	7.30	7.37	25.95	22.61	22.54	14.28	13.0	13.05
Total									
N	17	17	17	15	15	15	32	32	32
Mean (in.)	6.57	7.40	7.45	21.59	20.15	20.27	13.61	13.38	13.45

Note. ISRTP = in-season resistance training program; N = total number of participants; lbs = pounds; Pre = preseason; Mid = midseason; Post = postseason. P values comparing the three data points were: preseason to midseason p = .423; midseason to postseason p = .825; preseason to postseason p = .448.

Chapter 5

DISCUSSION

The purpose of this study was to examine lower extremity muscular power changes of collegiate basketball players throughout the course of a competitive season. The main findings were that there was a change in measured power production in collegiate basketball players over the course of a season as measured, in part, in vertical, horizontal, and lateral directions. There was a noted difference when comparing genders, as well as a measured difference in performance scores between groups that chose to utilize in-season resistance training and groups that did not. In addition, changes in performance scores between the training groups over the course of the season were different for the males as compared to the females.

McLean, Petrucelli, and Coyle studied maximal power output in conjunction with perceptual fatigue through the course of a collegiate soccer season. While the measures of fatigue during a sport season was outside the confines of this study as was the specificity of the sport of soccer the changes in muscle power falls in line with the interests of this project. Over the course of a sixteen week collegiate varsity soccer season, nineteen from a women's collegiate soccer team were assessed for peak power during preseason as well as eight times throughout the season in two week increments. This particular women's soccer team competed in twenty two games over the sixteen week season, as well as four team field practices and two resistance training practices per week. Mean maximal power over one revolution on an ergometer was calculated for the performance measure. Over the course of the season, the non-starters showed a similar result to this study in that maximal power did not deteriorate significantly over the course of the season. The starters for the soccer team showed a different response, however, as their lower extremity power values decreased throughout the season. The key to the difference in the McLean study between starters and non-starters was attributed to fatigue (McLean, Petrucelli, & Coyle, 2012). Although fatigue was outside of the confines of this current project, the author would like to note that while basketball and soccer both have a need for cardiovascular fitness that incorporates endurance and sprint performance, there is a difference in the overall distances traveled of the players of these two sports (soccer may require longer distances traveled overall as well as sprinted). In addition, basketball allows substitution of players much more freely which could potentially help alleviate potential fatigue over the course of a competitive season. It seems that McLean's study coincides with this research project in that a competitive sport season in conjunction with a resistance training program can maintain muscular power. It also further propagates this author's conclusion that fatigue during a competitive season is something for coaches to combat and efficiency of training should be given as much of a priority in an in-season resistance training program (ISRTP) as quality of prescribed exercise.

Lower-Body Strength

Lower extremity strength scores were collected in order to provide insight into a potential limiting factor in muscular power production. A muscle's ability to produce tensile force is a key component in a muscle's ability to produce velocity. Loads acting against the contracting muscle act as a "reverse load", therefore reducing the net force available to generate velocity (Guyton & Hall, 2006, Chapter 6). Therefore, the muscle's increased or decreased ability to generate tensile force can affect the velocity of contraction, and therefore, alter sport performance. Overall, the differences between male strength scores and female scores as well as the ISRTP group and non-ISRTP group came out as expected with males showing more strength than females and the ISRTP group showing more strength than the non-ISRTP group. While there was not a significant interaction between gender and ISRTP status, it could be an area of interest to the coaching community that the males who participated in the ISRTP showed a different trend through the course of the season. The male ISRTP population improved strength scores through the season with an overall mean improvement of 29.2 lbs. The male non-ISRTP mean scores decreased by 70.8 lbs from pre-season to post-season testing points which is consistent with previous research on non-ISRTP male basketball players (Hoffman, Fry, Howard, Maresh, & Kraemer, 1991). This also is consistent with research on strength changes during a competitive season in other sports (Hoffman & Kang, 2003; Utter et al., 1998; Marquez et all, 2008). It should also be noted that the pre-season leg press scores were 80.3 lbs higher in the ISRTP group. This is probably due to the presence of a pre-season resistance training program. While the change in lower extremity muscular strength was not statistically significant, the post-season testing data point shows a 100 lbs advantage when comparing the difference of the means of the ISRTP males and non-ISRTP.

Single Leg Vertical Leap

It was noted in the in-season resistance trained males that the mean single leg vertical leap score increased by one inch over the course of the entire season. Nine tenths of that inch increase occurred between the pre-season testing data point and the mid-season data point. Conversely, the non-resistance trained males showed only a slight change in the first half of the season with a decreasing trend and a drastic drop in mean single leg vertical jump height in the second half of their basketball season (decrease mean of 5.31 inches from mid-season to post-season). The mean pre-season testing scores for the males were surprising as the researcher was expecting the resistance trained group to have a higher mean single leg vertical leap score than the non-resistance trained males. Fatigue should not have been a confounding factor into the testing of any of the data points, but especially the post-season data point as this data were collected 7-10 days after the completion of the season. This leads to the conclusion that the presence of an in-season resistance training program, in conjunction with a varsity basketball season, not only helps to attenuate the loss of vertical leap height, and therefore muscular power in a vertical direction, over the course of the season, but also allowed the tested subjects to continue to increase vertical muscle power performance.

The results for the males are contrary to what Santos and Janeira (2009) found in their study published in 2009 in which they tested adolescent male basketball players. Santos and Janeira studied countermovement jump, squat jump, Abalakov test, and others tests to evaluate muscle power during a basketball season. Santos and Janeira found that there was no significant difference in muscular power output when comparing a reduced training ISRTP and a complete withdrawal from resistance training during a basketball season (Santos & Janeira, 2009). This leads to a conclusion that the neurological implications for the adolescent group could be taking precedent over potential muscle strength gains. Perhaps the reason for this is associated with the pubescent hormonal changes. The subjects in the adolescent study were ages 14-15 and were classified as being in stages 3 or 4 for genital development. However, the study did not attempt to measure hormonal levels.

On the other side of the spectrum, Gonzalez et al. (2013), allows us the opportunity to look at the muscle performance changes in professional male basketball players throughout an NBA season. By testing NBA players, Gonzalez found that an ISRTP coupled with a higher volume of playing time (starters), not only maintained vertical jump performance, but increased it as the season progressed (Gonzalez, et al., 2013). The number of participants were small for this study (n=7) due to team trades & injuries. Also of interest is that the team's ISRTP consisted of a reported regularity of eight to 12 sessions per month instead of once per week that was the norm for the two teams participating in this project. Despite this study's potential lack of statistical power, the presence of an ISRTP with male basketball players continues to be reinforced as an appropriate training tool. Similar results were seen when studying collegiate basketball players over the course of their competitive season. When evaluated for vertical power performance, male collegiate wresters showed very little change over the course of the season (participated in an ISRTP) (Utter, Stone, O'Bryant, Summiniski, & Ward, 1998).

Expressed earlier in this document were results that showed a significant interaction with gender and the presence of an ISRTP ($p < 0.001$). This information leads to a conclusion that the presence of an ISRTP seems to hold value with male basketball players. Hoffman, Fry, Howard, Maresh, and Kraemer (1991) further illustrates this point with their study on NCAA Division I collegiate basketball players. With a lack of an ISRTP, the basketball players showed a decrease in vertical power performance at the mid-season mark by a mean of 5.6cm which is consistent with the trend seen in this study in which a decrease of 1.91cm (.75in) was observed. Hoffman et al. did observe a different trend as the subjects in their study showed an improvement in vertical power scores in the second half of the competitive season while this study observed a sharp decline in vertical power performance in the non-ISRTP male sub-group.

Both resistance trained and non-resistance trained females showed a decrease in mean vertical leap height in the first half of the competitive season. The resistance trained group showed a decrease in mean vertical jump performance by 1.1875 inches whereas the non-resistance trained females only showed a 0.25 inch deficit in mean vertical jump performance. Both of these populations showed an increase of more than an inch at the post-season testing time when compared to the mid-season performances. This may indicate a fatiguing effect of in-season resistance training in female basketball populations through the course of the season. Gathering data 7-10 days after completion of the competitive season may have offered the subjects time to recover from effects of a potentially chronically fatiguing varsity season.

In 1993 Hakkinen published a study in which he recruited 10 female basketball players competing in the official league in Finland. Subjects competed in a nine week Season I competitive season, followed by a three week training hiatus, and ending in a 10 week Season II competitive season. The team participated in an ISRTP consisting of one resistance training session per week in which the subjects performed one to two resistance training exercises ranging from 30-80% of the subjects 1RM. In addition, the subjects would engage in a plyometric training session approximately once every two weeks. Vertical jump scores, isometric knee extension force, anaerobic power, VO2 max, and body fat measurements were taken pre-season, after Season I, and after Season II. Results of this study show that there were no statistically significant changes of the subjects in any of the measurements taken over the course of Season I and II (Hakkinen, 1993a). Hakkinen's study on female basketball players supports findings from this study that ISRTPs do not significantly change performance measurements in female basketball players. Hakkinen also published in the same year a similar study in competitive female volleyball players. Once again, Hakkinen used vertical jump as part of testing instrument, and as he had done with his female basketball study, he tested his subject pre-season, between Season I and II, and post-season. This time, Hakkinen observed a significant increase in Season I for vertical jump height scores in the experimental group. Season II, however did not match the results of season I and vertical height scores decreased. Potential reasons for these different finding were attributed to the cessation of maximal strength training for Season II. While there were no significant differences in vertical jump scores of the control group, it should be noted that the control group still participated in ISRTP approximately once or twice per week while the experimental group participated in a ISRTP two to three times per week. Hakkinen's results with his control group for volleyball players match the results of this study, as did his results with basketball players. The observed difference in vertical jump height in the experimental group that is inconsistent with the present study could be attributed to the increased training stimulus of resistance training two to three times per week. Siegler, Gaskill, and Ruby (2003) also showed little difference in vertical height scores when studying performance change in female athletes over the course of a competitive varsity season. Even though Siegler et al. study used female high school soccer players, the muscle performance results were similar to this study. Siegler et al. found that vertical jump height was not significantly impacted with the presence of an ISRTP (Siegler, Gaskill, & Ruby, 2003). It should be noted that the study on the female soccer players differed from this study in that it mandated ISRTP twice per week instead on once. Even with the additional resistance exercise stimulation there was little change over the course of the season which further illustrates the apparent inefficiency of an ISRTP for female athletes.

Not all research on female athlete vertical power performance leads to this same conclusion. Marques, Tillar, Vescovi, and Gonzalez-Badillo (2008) studied muscular strength and power performance in female professional volleyball players over the course of a competitive season. The volleyball players had completed a pre-season training program which should offset potential new neurological adaptations with the ISRTP. Significant improvements were made with the ISRTP in both loaded and unloaded counter-movement jumps over the course of the season. Why would Marques et al's. study show such different results? The answer may be found in the populations studied. The professional volleyball players may not have as hectic of a schedule when compared to student athletes. The student athletes could have additional daily tasks and responsibilities that could have a fatiguing effect on the student athlete. This could include sacrificing sleep in order to complete academic assignments or engage in social activities that could negatively affect the amount of energy recovery. It is also possible that because the student athletes have a number of different demands placed on them, some of them may not put as much effort into their sport and training sessions. It is also possible that some of them may not adhere to a disciplined nutrient rich dietary intake and sleep schedule that could allow for a more efficient recovery process after training stimuli.

Single-Leg Lateral Leap

While not statistically significant the male basketball players showed an interesting trend with the presence of an in-season resistance training program. While little difference is seen in the pre-season and post-season testing scores there was a distinct and opposite trend for the two groups at the mid-season testing time. It appears that the in-season resistance program was beneficial during the first half of the season but that trend did not continue in the second half.

When evaluating the plot for the female ISRTP population the pre-season and post-season lateral leap scores were very similar, just as they were in the male scores. However, the differences at the mid-season data collection times showed a mean increase of 22cm while the non-IRSTP population showed a decrease in lateral leap performance in the first half of the season and a steeper decline in lateral leap performance during the second half of the season. It should also be noted that the mean pre-season lateral leap scores were nearly identical and became more divergent as the season progressed. While the 22 cm increase in mean lateral leap score was seen in the female non-ISRTP, a continued trend of decreased performance was seen in the ISRTP female population. The gender interaction with the presence of an ISRTP that was observed with the overall evaluation of data (MANOVA with repeated measures) seems relevant, while not statistically significant. The trend of this study for females not depending on an ISRTP for maintenance of muscular power continued. Literature with this specific movement direction appears to be absent, which highlights the need for this project.

Single Leg Horizontal Leap

Overall there was very little observed change in lower extremity muscular power measured in a forward horizontal direction. The male horizontal leap scores over the course of the competitive basketball season changed very little (difference of the means = 3.2 cm) when comparing pre-season and post-season scores. The female subjects showed a small improvement in mean single leg horizontal leap scores at the mid-season testing time (difference of the means= 10.17cm) and a subsequent decrease at the post-season testing data point when compared to pre-season (difference of the means = 4.39 cm) and the mid-season (difference of the means = 14.56 cm). The trends of change over the course of the season between the sub-grouping of females with an ISRTP, females without an ISRTP, and males with an ISRTP all followed very similar patterns throughout the course of the competitive season. While the pattern of change for muscular power measured in a forward horizontal movement moved in different directions between males with or without an ISRTP, the difference in distance appears inconsequential.

Margaria-Kalamen

This measurement showed that males had in increased capacity to produce muscular power than females. In particular, the females showed little change in muscular power over the course of the season, whereas the males showed a mid-season decrease in the non-resistance training group and an increase in the resistance training group. After the mid-season data collection, males in the non-resistant training group recovered some of the observed lost power production from the first half of the season. The difference between the male group engaging in an ISRTP and the males that did not may be due to the muscular strength trends through the season. While not linear in relationship, the ISRTP males increased in muscle strength throughout the season which may have allowed for increases in power production. There may also be a fatigue component present. This may explain why there was a recovery of power production seen at the post-season data point as this data was collected 7-10 days after the final game of the team's season. More research is warranted in this area because fatigue alone may explain the drop in mid-season muscle power of the non-ISRTP, it does not explain the lack of increase in muscle power production of the ISRTP at the post-season testing time. If there was a fatiguing effect due to the competitive season, and since each team had the same amount of recovery time from the end of their season until the final testing time, it seems logical to conclude that the ISRTP males would have an equal change in Watt production when comparing the mid-season and post-season data points for the Margaria-Kalaman test. However, this was not the case in this research project. The difference in the pattern of change deserves more scrutiny and should be researched further.

5-10-5 Shuttle Run

Females seemed to decrease power measured by the athletes' ability to achieve a higher run velocity, decelerate, change directions, and again achieve a high run velocity as reflected by slower shuttle times than males over the course of the season. In-season resistance training was not a significant factor by itself in the times recorded for the shuttle run. However, in conjunction with gender, a significant interaction manifested. Males recorded slower times at the mid-season point and then rebounded during the post-season testing time. Over time, females who did not participate in an in-season resistance training program recorded slower shuttle times at the post-season data collection point than they did at the pre and mid-season data collection times. Males that did not participate in a resistance training program had their slowest times at mid-season. When comparing the male non-ISRTP to the 1991 Hoffman study, the Hoffman study showed a small but steady improvement in multidirectional agility scores with a T test which is consistent with the male ISRTP group from this project (Hoffman, Fry, Howard, Maresh, & Kraemer, 1991). In the non-ISRTP male scores for muscular power measured through quickness, a decline in 5-10-5 shuttle performance was observed at the mid-season mark with a recovery of performance in the second half of the season. Perhaps, this is due to fatigue at different time points in the season. Hoffman et al. observed no differences in times over a men's collegiate basketball season when assessing "quickness" utilizing a T-test (Hoffman, Fry, Howard, Maersh, & Kraemer, 1991). While this is contrary to the findings of this study, the T-test incorporates a different movement pattern that make a direct comparison of the 5-10-5 shuttle run and T-test difficult. In addition, the T-test incorporates a lateral slide component to the movement pattern which allows a sport specific skill to the evaluation procedure. This sport specific skill may allow the subjects higher amount of training stimulus throughout the course of the season with this specific skill.

Overall observations of the teams allowed the researcher to see that the teams appeared to prepare for their game earnestly. The author admits not attending all the practices for all teams involved in this study, the practices that the author did attend were well organized with little wasted time. Drills were done with intensity and purpose, and this seemed to help their game performance. Each team involved in this study was very competitive in their respective leagues with three out of the four teams qualifying for national tournament participation. When evaluating the performance variables through the course of this study, the author noted that the male ISRTP group had a decrease in performance at mid-season with a rebound in performance at the post-season data point. The coach for this particular population within this study had a reputation for intensity and toughness. This may account for some of the reclamation of performance at the post-season data point as the subjects may have been impacted more by the 7-10 days of recovery. The only exceptions to this pattern were the estimated leg press and single leg vertical leap. This further supports the usefulness of an ISRTP in males. The presence of an ISRTP not only attenuated the loss of muscular power through the basketball season, it also allowed for small increases in muscular strength.

Practical Applications

The competitive collegiate basketball season offers many challenges to players and coaches alike. Becoming efficient in energy expenditure and time are becoming increasingly important as student athletes must balance class schedules, coursework, basketball practice schedule, travel schedule, injury treatments, and ISRTP schedule. With a limit of 20 hours per week that is allotted for basketball practice, training, and game time the use of an ISRTP must be managed appropriately in order for a basketball team to reach their full potential. The goal, of course, is for a team to perform well during the course of a season in order to position themselves well to enter post season play while peaking both skill and physical performance during post season play in order to win conference and national championships. Resistance training has long been proven to be beneficial in improving muscular performance and so it seems only natural to continue to incorporate an ISRTP into a competitive basketball season.

The question that the author has attempted to answer with this study was if the incorporation of an ISRTP meets the expectations of the players and coaching staff in reaching their goals for muscular performance maintenance and improvement.

It appears that the effects of an ISRTP had different effects on the males and females recruited for this study. While not the case in all the performance tests the overall trend seems to be that ISRTPs are an inefficient use of precious time and energy during a competitive season for female basketball players. Males, on the other hand, could benefit from continued resistance training throughout the course of a competitive season. It is not unusual for both men's and women's basketball programs to participate in ISRTPs to maintain and improve performance. With the evidence presented in this study, scrutiny is warranted in the planning and prescription of women's ISRTPs. After evaluating the data gathered with this project, strength and conditioning coaches should be hesitant to incorporate an ISRTP with women's basketball teams. The time and effort spent with an ISRTP could be better used in development of sport skills or for recovery of energy stores for the next basketball practice of game.

The concept of periodization has been successfully incorporated into strength and conditioning programs in basketball and other sports for decades. It remains a cornerstone principle for the year long process of managing resistance training programs that allow coaches and exercise professionals to enhance muscle performance characteristics that, in turn, enhance sport performance. With a proper periodization model in place a resistance training program that includes an ISRTP can be implemented safely, allowing for performance increases while at the same time decreasing likelihoods of staleness, burnout, or even increased fatigue. As exercise professionals working with a basketball team, or any other sport, this author believes that it is critically important for exercise professionals to remember that the athletes we train are training as a means to an end. That end goal, for most, is to enhance sport performance. Incorporating what has been learned from this study and combining it with the periodization models means that efficiency of training should always be sought out by the exercise professional, but becomes most important during the mesocycle that would utilize an ISRTP.

Chapter 6

SUMMARY, CONCLUSION, AND RECOMMENDATIONS

Summary

The purpose of this study was to evaluate changes in muscle power performance in a horizontal (forward movement), vertical, and lateral directions in collegiate basketball players. Four collegiate basketball teams were recruited for this project. Two teams were female and two teams were male. One team in each gender category participated in an ISRTP and one team in each gender category did not participate in an ISRTP. After statistical analysis through a MANOVA with repeated measures of Margaria-Kalaman, single leg horizontal leap, single leg vertical leap, single leg lateral leap, 5-10-5 shuttle run, and estimated RM leg press that the presence of an ISRTP had a significant impact ($p < 0.001$) on muscle power performance tests throughout the competitive season. A significant interaction ($p < 0.001$) was seen between gender and the presence of an ISRTP.

Conclusions

Overall, this research project supports the use of an ISRTP for collegiate basketball players. Specifically, the use of an ISRTP seemed to benefit males more than females. More specifically, these benefits seemed the most beneficial to the movements that propel the basketball players in a forward horizontal direction (single leg horizontal leap and shuttle run). There was an observed difference between genders ($p< 0.001$). Benefits seen in the estimated RM leg press followed the principle of specificity and were as expected. Muscle power measured in a vertical direction (Margaria-Kalaman and single leg vertical leap), and muscle power measured in a lateral direction (single leg lateral leap) only gender showed to have statistical significance ($p<0.001$). Overall, this researcher recommends the use of an ISRTP for collegiate male basketball players but not female basketball players due to the data collected with this study.

Recommendations for Future Study

Recreation of this study.

Recommendations for recreation of this study would be to purchase a second wireless digital timing system. The timing system was a necessary tool for both the Margaria-Kalaman test and the 5-10-5 shuttle test. In addition, the wireless digital timing system was used to gather pilot data for an experimental field test measuring muscular power in a lateral direction. Due to the frequency of using the wireless digital timing device, the amount of time needed to complete the testing of this study could have been decreased with a second timer. It may also be beneficial to place the post-season testing data collection point only two or three days after the last competition. Each of the four different teams participating in this study ended their season while their respective institutions were on spring break. Subsequently, the subjects left their respective campuses for spring break before appropriate testing could occur. While this allowed the researcher to maintain consistency for the time of data collection of the teams, it also may have allowed an increased amount of recovery following the cessation of their competitive seasons.

Future Studies.

Future studies should evaluate the fatiguing effects of a basketball season on collegiate athletes. While outside the parameters of this study, this author can’t help but wonder about the effects of physiological, mental, and emotional stressors of a student athlete has on a competitive season. Do coaching staffs allow for enough rest during the recovery portion of a training cycle to allow for replenishment of energy stores, adaptations occurring as a result of training, and potential healing from microtrauma injuries? How much, if any, does mental fatigue affect a student athlete? Is there an amount of mental fatigue from sport practice that affects coursework? Does the amount of course work affect mental focus exerted during sport practice or a game during a season? Do different majors chosen by the student athlete affect mental focus during practice and games? What effect does emotional stress have on a collegiate sport season?

Other questions that arose directly from this study reside in validity tests. The Margaria-Kalaman test uses vertical height to calculate power exhibited from the subject even though vertical and horizontal (forward motion) are executed in order to climb the stairs. Could the horizontal distance traveled by the subjects give a more accurate calculation? Could the calculated tangent of the right triangle with the vertical height and horizontal distance give a more accurate calculation of muscle power exerted by the subjects?

The single leg lateral leap test also proved to leave questions on the best method for conducting the test. While the validity of the test has been established, the method used to perform the single leg lateral leap lacked details. The researcher of this project chose to use the trail leg of the subject instead of the lead leg because it seemed a more natural movement. The author also chose to instruct the subject to land with the same leg (trail leg) in order to potentially reduce the amount of influence leg length would have by landing on the opposite leg (lead leg). While the author maintains that the single-leg lateral leap testing procedure used in this study is valid, it is undetermined if it is best. The possibility of using the lead leg as the jumping leg should be evaluated as a valid tool as well as allowing the subjects to jump with their trail leg and land on their lead leg. This third option that allows for the subject to jump with the trail leg and land with the lead leg could require accommodation for leg length, but it is also likely to allow for the most natural movement out of the proposed procedures for single-leg lateral leap. This more natural movement could allow a greater level of comfort, and therefore allow subjects to jump more aggressively and more closely achieve peak muscular power in the lateral direction, therefore allowing a more accurate measurement of peak muscle power.

REFERENCES

Aagaard, P., Simonsen, E.B., Andersen, J. L., Magnusson, P. & Dyhre-Poulsen, P. (2002). Increased rate of force development and neural drive of human skeletal muscle following resistance training. *Journal of Applied Physiology, 93*, 1318-1326.

Anderson, L., Anderson, J., Magnussen, S., Suetta, C., Madsen, J., Christensen, L., & Aagaard, P. (2005). Changes in human muscle force-velocity relationship in response to resistance training and subsequent detraining. *Journal of Applied Physiology*, *99*, 87-94. doi:10.1152

Atha, J. (1981). Strengthening muscle. *Exercise and Sport Science Reviews*, 9(1), 1-74.

Baechle, T. R. (1994). *Essentials of Strength Training and Conditioning*, (1st ed.). Champaign, IL: Human Kinetics.

Baker, D., & Nance, S. (1999). The relation between running speed and measures of strength and power in professional rugby league players. *Journal of Strength and Conditioning Research*, *13*, 230-235.

Baker, D., Wilson, G., & Carlyon, R. (1994). Periodization: The effect on strength of manipulating volume and intensity. *Journal of Strength and Conditioning Research*, *8*(4), 235-242.

Barnes, J. L., Schilling, B. K., Falvo, M. J., Weiss, L. W., Creasy, A. K., Fry, A. C. (2007). Relationship of jumping and ability performance in female volleyball athletes. *Journal of Strength and Conditioning Research, 21*(4), 1192-1196.

Beutler, A. I., Motte, S. J., Marshall, S. W., Padua, D. A., & Boden, B. P. (2009). Muscle strength and qualitative jump-landing differences in male and female military cadets: The jump-ACL study. *Journal of Sports Science and Medicine, 8*, 663-671.

Brooks, G.A., Fahey, T.D, & Baldwin, K.M. (2005). *Exercise physiology*: Human bioenergetics and its application (4^{th} ed.). Boston: McGraw-Hill.

Brooks, S., & Falulkner, J. (2001). Maximum and sustained power of extensor digitorum longus muscles from young adult, and old mice. *Journal of Gerontology, 46*(1), 28-33.

Caterisano, A., Patrick, B., Edenfield, W., & Batson, M. (1997). The effects of a basketball season on aerobic and strength parameters of collegiate men: Starters vs reserves. *Journal of Strength and Conditioning Research 11*(1), 21-24.

Cavagna, G. (1977). Storage and utilization of elastic energy in skeletal muscle. *Exercise and Sports Science Review*, *5*(1), 89-129.

Chiu, L. (2008). Does an optimal load exist for power training. *Strength and Conditioning Journal*, *30*(2), 67-69.

Cronin, J., & Hansen, K. (2005). Strength and power predictors of sports speed. *Journal of Strength and Conditioning Research, 19*(2), 349-357.

Cronin, J., Ogdon, T., Lawton, T., & Brughelli, M. (2007). Does increasing maximal strength improve sprint running performance? *Strength and Conditioning Journal*, *29*, 86-95.

Dreyer, H. C., Schroeder, E. T., Hawkins, S. A., Marcell, T. J., Tarpenning, K. M., Kyle, M., . . . Wiswell, R. A. (2006). Chronic exercise and skeletal muscle power in older men. *Applied Physiology, Nutrition & Metabolism*, *33*(3), 190-195. doi:10.1139/H05-014

Earles, J. (1989). Implementing a junior varsity strength program for female athletes. *National Strength and Condioning Association Journal*, 11(3), 32-34.

Faigenbaum, A. D., Westcott, W. L., Micheli, L. J., Outerbridge, A. R., Long, C. J., LaRosa-Loud, R., Zaichkowsky, L. D. (1996).The effects of strength training and detraining on children. *Journal of Strength and conditioning Research, 10*(2), 109-114.

Fernadez-Rio, J. Terrados, N., Fernandez-Garcia, B., & Suman, O. E. (2010). Effects of vibration training on force production in female basketball players. *Journal of Strength and Conditioning Research, 24*(5), 1373-1380.

Field, R. (1991). Explosive power test scores among male and female collegiate athletes. *National Strength and Conditioning Association Journal*, 13(3), 50.

Fleck, S.J. (1994). Detraining: Its effects on endurance and strength. *Journal of Strength and conditioning Research*, *16*(1), 22-28.

Garhammer, J. (1993). A review of power output studies of Olympic and powerlifting: Methodology, performance, prediction, and evaluation tests. *Journal of Strength and Conditioning Research,* (7)2, 76-89.

Garstecki, M.A., Latin, R.W., Cuppett, M.M. (2004). Comparison of selected physical fitness and performance variable between NCAA Division I and II football players. *Journal of Strength and Conditioning Research*, 18(2), 292-297.

Gonring, B. (2010). *Block Periodization in the Sport of Powerlifting*. Retrieved from http://www.elitefts.com/documents/block_periodization.htm

Gonzalez, A. M., Hoffman, J.R., Rogowski, J.P., Burgos, W., Manalo, E., Weise, K., Fragala, M.S., & Stout, J.R. (2013). Performance changes in NBA basketball players vary in starters vs. non-starters over a competitive season. *Journal of Strength and Conditioning Research*, 27(3), 611-615.

Guyton, A. C., & Hall, J. E. (2006). *Textbook of medical physiology* (11th ed.). Philadelphia: Elsevier Saunders.

Hakkinen, K. (1993a). Changes in physical fitness profile in female basketball players during the competitive season including explosive type strength training. *The Journal of Sports Medicine and Physical Fitness*, 33(1), 19-26.

Hakkinen, K. (1993b). Changes in physical fitness profile in female volleyball players during the competitive season. *The Journal of Sports Medicine and Physical Fitness*, 33(3), 223-236.

Hall, S. J. (2003). *Basic biomechanics*. Boston: McGraw-Hill Higher Education.

Harris, N., Cronin, J. B., & Hopkins, W. G. (2008). Squat jump training at maximal power and loads vs heavy loads: effects on sprint ability. *Journal of Strength and Conditioning Research*, *22*(6), 1742-1749.

Hartmann, H., Bob, A., Wirth, K., & Schmidtbleicher, D. (2009). Effects of different periodization models on rate of force development and power ability of the upper extremity. *Journal of Strength and Conditioning Research*, *23*(7), 1921-1932.

Heitkamp, H., Mayer, F., Fleck, M., & Hortsman, T. (2002). Gain in thigh muscle strength following balance training in male and female judokas. *Isokinetics and Exercise Science*, 10(1), 199-202.

Hoffman, J., Fry, A., Howard, R., Maresh, C., & Kraemer, W. (1991). Strength, speed and endurance changes during the course of a division I basketball season. *Journal of Applied Sport Science Research*, *5*(3), 144-149.

Hoffman,J., Kang, J. (2003). Strength changes during an in-season resistance-training program for football. *Journal of Strength and Conditioning Research*, 17(1), 109-114.

Henwood, T. R., Riek, S., & Taffe, D. R. (2008). Strength vs muscle power-specific resistance training in community-dwelling older adults. *The Journals of Gerontology*, *63A*(1), 83-91.

Hewett, TE., Lindenfeld, TN., Riccobene, JV., & Noyes, FR (1999). The effect of neuromuscular training on the incidence of knee injury in female athletes. A prospective study. *American Journal of Sports Medicine*, *27*, 699-706.

Hewett, TE., Stroupe, AL., Nance, TA., & Noyes, FR (1996). Plyometric training in female athletes. Decreaed impact forces and increased hamstring torques. *American Journal of Sports Medicine 24*, 765-773.

Hoffman, J.R., Fry, A.C., Howard, R., Maresh, C.M., Kraemer, W.J. (1991). Strength, speed, and endurance changes during the course of a division I basketball season. *Journal of Applied Sport Science Research*, 5(3), 144-149.

Houston, M. E. (2006). *Biochemistry primer for exercise science*. Champaign, IL: Human Kinetics

Ivey, F.M., Tracy, B.L., Lemmer, J.T., NessAiver, M., Metter, E.J., Fozard, J.L. & B.F. Hurley. (2000). Effects of strength training and detraining on muscle quality: Age and gender comparisons. *Journal of Gerontology, 55A*(3), B152-B157.

Izquierdo, M., Ibañez, J., González-Badillo, J. J., Ratamess, N. A., Kraemer, W. J., Häkkinen, K., . . . Gorostiaga, E. M. (2007). Detraining and tapering effects on hormonal responses and strength performance. *Journal of Strength and Conditioning Research, 21*(3), 768-775.

Jones, H. K. (1997). The effects of varying resistance training loads on intermediate and high velocity-specific adaptations (Doctoral dissertation, University of Alabama).

Kawamori, N., & Haff, G. F. (2004). The optimal training load for the development of muscular power. *Journal of Strength and Conditioning Research*, *18*(3), 675-684.

Korkmaz, C., & Karahan, M. (2006). A comparative study on the physical fitness and performance of male basketball players in different divisions. *University Journal of Physical Education and Sport Science,*6(1), 16-26.

Kraemer, W.J., Duncan, N.D., & Volek, J.S. (1998). Resistance training and elite athletes: Adaptations and program consideration. *Journal of Orthopedic Sports Physiology Therapy*, *28*, 110-119.

Kraemer, W.J., Hakkinen, K., Triplett-McBride, N.T., Fry, A.C., Koziris, L.P., Ratamess, J.E., Knuttgen, H.G. (2003). Physiological changes with periodized resistance training in women tennis players. *Medical Science in Sports Exercise. 35*, 157-168.

Kraemer, W. J., Koziris, L. P., Ratamess, N. A., Häkkinen, K., Triplett-McBride, N. T., Fry, A. C., . . . Fleck, S. J. (2002). Detraining produces minimal changes in physical performance and hormonal variables in recreationally strength-trained men. *Journal of Strength and Conditioning Research, 16*(3), 373-382.

Kraemer, W.J., Mazzetti, B.C., Nindl, B.C., Gotshalk, L.A., Volek, J.S., Bush, J.A.,…Hakkenin, K. (2001). Effect of resistance training on women's strength/power and occupational performances *Medical Science in Sports Exercise. 33*, 1011-1025.

Lesmes, G.R., Costill, D.L., Coyle, E.F., Fink, W.J. (1978). Muscle strength and power changes during maximal isokinetic training. *Medicine and Science in Sports*. 10(4), 266-269.

LaSuer, D. A., McCormick, J. H., Mayhew, J. L., Wasserstein, R. L., & Arnold, M. D. (1997). The accuracy of prediction equations for estimating 1-RM performance in the bench press, squat, and deadlift. *Journal of Strength and Conditioning Research, 11*(4), 211-213.

Lemmer, J. T., Hurlbut, D. E., Martel, G. F, Tracy, B. L., Ivey, F. M., Metter, E. J., Fozard, J. L., Fleg, J. L., & Hurley, B. F. (2000). Age and gender responses to strength training and detraining. *Journal of the American College of Sports Medicine, 32*(8), 1505-1512.

Liebermann, D. G., & Katzb, L. (2003). On the assessment of lower-limb muscular power capabilities. *Isokinetics and Exercise Science*, *11*, 87-94.

Lindle, R.S, Metter, E.J., Lynch, N.A., Fleg, J.L., Tobin, F.J., Roy, T.A., Hurley, B.F. (1997). Age and gender comparisons of muscle strength in 654 men and women aged 20-93 yr. *Journal of Applied Physiology,* 83(1), 1581-1587.

Luttgens, K., & Hamilton, N. (1997). *Kinesiology: Scientific basics of human motion* (9th ed.). Madison, WI: Brown Benchmark.

Marina, M., Jemni, M., Rodriguez, F. A., & Jimenez, A. (2012). Plyometric jumping performance of male and female gymnasts from different heights. *Journal of Strength and Conditioning Research, 26*(7), 1879-1836.

Marques, M.A.C., & Gonzalez-Badillo, J.J. (2006). In-season resistance training and detraining in professional team handball players. *Journal of Strength and Conditioning Research*, *20*(3), 563-571.

Marques, M.C., Tillar, R.V.D., Vescovi, J.D., & Gonzalex-Badillo, J.J. (2008). Changes in strength and power performance in elite senior female professional volleyball players during the in-season: a case study. *Journal of Strength and Conditioning Research*, 22(4), 1147-1155.

McEvoy, K.P., & Newton, R.U. (1998). Baseball throwing speed and base running speed: The effects of ballistic resistance training. *Journal of Strength and Conditioning Research*, 12(4), 216-221.

McLean, B. D., Petrucelli, C., & Coyle, E. F. (2012). Maximal power output and perceptual fatigue responses during a division I female collegiate soccer season. *Journal of Strength and Conditioning Research, 26*(12), 3189-3196.

Melnyk, J., Rogers, M., & Hurley, B. (2009). Effects of strength training and detraining on regional muscle in young and older men and women. *European Journal of Applied Physiology, 105*, 929-938. doi: 10.1007/s00421-008-0979-0

Meylan, C., McMasters, T., Cronin, J., Mohammed, N., Rogers, C., & deKlerk, M. (2009). Single-leg, lateral, horizontal, and vertical jump assessment: Reliability, interrelationships, and ability to predict sprint and change-of-direction performance. *Journal of Strength and Conditioning Research, 23*(4), 1140-1147.

Mougious, V. (2006*). Exercise Biochemistry*. Champaign, IL: Human Kinetics.

Myer, G. D., Ford, K. R., Palumbo, J. P., & Hewett, T. E. (2005). Neuromuscular training improves performance and lower-extremity biomechanics in female athletes. *Journal of Strength and Conditioning Resarch, 19*(1), 51-60.

National Strength and Conditioning Association. (2008). Approaching physical preparation for youth team-sports players. *National Strength and Conditioning Association Journal*, *30*(1), 29-42.

National Strength and Conditioning Association. (1993). Position statement: Explosive exercises and training. *National Strength and Conditioning Association Journal*, *15*(3), 6.

National Strength and Conditioning Association. (2009). National strength and conditioning association: strength and conditioning professional standards and guidelines. *National Strength and Conditioning Association Journal, 31*(5), 14-38.

Newton, R.U., Dugan, E. (2002). Application of strength diagnosis. *Journal of Strength & Conditioning,* 24(5), 50-59.

Newton, R. U., Kraemer, W. J. (1994). Developing explosive muscular power: implications for a mixed methods training strategy. *Strength and Conditioning, 16*(20), 20-31.

Nimphius, S., McGuigan, M. R., & Newton, R. U. (2010). Relationship between strength, power, speed, and change of direction performance of female softball players. *Journal of Strength and Conditioning Research, 24*(4), 885-895.

Noyes, F. R., Barber-Westin, S. D., Smith, S. T., & Campbell, T. (2011). A training program to improve neuromuscular indices in female high school volleyball players. *Journal of Strength and Conditioning Research, 25*(8), 2151-2160.

Peterson, M.D., Alvar B.A., & Rhea, M.R. (2006). The contribution of maximal force production to explosive movement among young collegiate athletes. *Journal of Strength and Conditioning Research*, 20(4), 867-873.

Potteiger, J. A., Lockwood, R. H., Haub, M. D., Dolezal, B. A., Almuzaini, K. S., Schroeder, J. M., et al. (1999). Muscle power and fiber characteristics following 8 weeks of plyometric training. *Journal of Strength and Conditioning Research*, *13*(3), 275-279.

Powers, S. K., & Howley, E. T. (2001). *Exercise physiology* (4th ed.). Boston: McGraw Hill.

Prestes, J., Frollini, A. B., De Lima, C., Donatto, F. F., Foschini, D., Marquetti, R., . . . Fleck SJ. (2009). Comparison between linear and daily undulating periodized resistance training to increase strength. *Journal of Strength and Conditioning Research*, *23*(9), 2437-2442.

Radcliffe, J. C., & Farentinos, R. C. (1999). *High-powered plyometrics*. Champaign, IL: Human Kinetics.

Rhea, M., Ball, S., Phillips, W., & Burkett, L. (2002). A comparison of linear and daily undulating periodization with equated volume and intensity for strength. *Journal of Strength and Conditioning Research*, *16*(2), 250-255.

Ross, R. E., Ratamess, N. A., Hoffman, J. R., Faigenbaum, A. E., Kang, J., & Chilakos, A. (2009). The effects of treadmill sprint training and resistance training on maximal running velocity and power. *Journal of Strength and Conditioning Research*, *23*(2), 385-394.

Runge, M., Rittweger, J., Russo, C.R., Schiessl, H., & Dieter, F. (2004). Is muscle power output a factor in the age-related decline in physical performance? A comparison of muscle cross section, chair-rising test and jumping power. *Clinical Physiology and Testing Imaging*, *24*(6), 335-340.

Santos, E. J., Janeira, M. A. (2009). Effects of reduced training and detraining on upper and lower body explosive strength in adolescent male basketball players. *Journal of Strength and Conditioning Research*, *23*(6), 1737-1744.

Siegler, J., Gaskill, S., & Ruby, B. (2003). Changes evaluated in soccer-specific power endurance either with or without a 10-week, in-season, intermittent, high-intensity training protocol. *Journal of Strength and Conditioning Research*, (17)2, 379-387.

Schlotz, M. K., Potteiger, J. A., Huntsinger, P. G., & Denmark, L. C. (1998). The short-term effects of periodized and constance-intensity training of body composition, strength, and performance. *Journal of Strength and Conditioning Research*, 12(3),173-178.

Schmidtbleicher, D. (1992). Training for power events. *Strength and Power in Sport*, *1*, 381-395.

Schneider, V., Arnold, B., Martin, K., Bell, D., & Crocker, P. (1998). Detraining effects in college football players during the competitive season. *Journal of Strength and Conditioning Research*, *12*(1), 42-45.

Tanton, L., Cappaert, T., Gordon, P., Zoeller, R., Angelopoulos, T., Price, T., …Visich, P. (2009). Strength, size, and muscle quality in the upper arm following unilateral training in younger and older males and females. *Clinical Medicine: Arthritis and Musculskeletal Disorders*, 9-18. Retrieved from http://paeir.med.umich.edu/paeir/files/tanton_2009.pdf

Tokmakidis, S.P., Kalapotharakos, V.I., Smilios, I., & Parlavantzas, A. (2009). Effects of detraining on muscle strength and mass after high or moderate intensity of resistance training in older adults. *Scandinavian Society of Clinical Physiology and Nuclear Medicine*, *29*, 316-319. Doi: 10.1111/j.1475-097x.2009.00866.x.

Tucci, J.T., Carpenter, D.M., Pollock, M.L., Graves, J.E., & Leggett, S.H. (1992). Effect of reduced frequency of training and detraining on lumbar extension strength. *Spine*, *17*(12), 1497-1501.

Utter, A., Stone, M., O'Bryant, H., Summinski, R., & Ward, B. (1998). Sport-seasonal changes in body composition, strength, and power of college wrestlers. *Journal of Strength and Conditioning Research*, 24(4), 266-271.

Vissing, K., Brink, M., Lonbro, S., Sorensen, H., OverGaard, K., DanBorg, K., et al. (2008). Muscle adaptations to plyometric vs resistance training in untrained young men. *Journal of Strength and Conditioning Research*, *22(6),* 1799-1810.

Walsh, M. S., Waters, J. A., Bohm, H., & Potteiger, J. A. (2007). Gender bias in jumping kinetics in national collegiate athletic association division I basketball players. *Journal of Strenght and Conditioning Research, 21*(3), 958-962.

Walshe, A. D., Wilson, G. J., & G. J. C. Ettema (1998). Stretch-shorten cycle compared with isometric preload: contribution to enhanced muscular performance. *Journal of Applied Physiology*, *84*(1), 97-106.

Weyand, P., Sternlight, D., Belizzi, M., & Wright S. (2000). Faster top running speeds are achieved with greater ground reaction forces and not more rapid leg movements. *Journal of Applied Physiology*, *89*(5), 1991-1999.

Willoughby. (1993). The effects of mesocycle-length weight training programs involving periodization and partially equated volumes on upper and lower body strength. *Journal of Strength and Conditioning Research, 7*(1), 2-8.

Winchester, J. B., McBride, J. M., Maher, M. A. Mikat, R. P., Allen, B. K., Kline, D. E., . . . Michael, R. (2008). Eight weeks of ballistic exercise improves power independently of changes in strength and muscle fiber type expression. *Journal of Strength and Conditioning Research*, *22*(6), 1729-1734.

Wilson, G.J., Newton, R.U., Murphy, A.J., Humphries, B.J. (1993). The optimal training load for the development of dynamic athletic performance. *Medicine & Science in Sports & Exercise*, 25(1), 1279-1286.

Appendix A

Informed Consent

Title: Effects of an American basketball season on lower extremity power output in collegiate basketball players.

Researcher(s)	Compliance Contact Person
Name: Kevin King	Ro Windwalker, Compliance Coordinator
Faculty Advisor: Dr. Inza Fort	
University of Arkansas	Research Compliance
College of	University of Arkansas
Department of Kinesiology	210 Administration Hall
1111 N. Glenstone Ave	Fayetteville, AR 72701-1201
Springfield MO, 65802	479.575.2208
xxx.xxx.xxxx Ext xxxx	irb@uark.edu

Description: This study will investigate the effects of a collegiate basketball season on lower extremity power performance in collegiate basketball players. You will be asked to perform a single leg vertical, horizontal and lateral leap test, a Margaria-Kalamen power test, a lateral slide board test, a pro shuttle run, and an estimated maximal leg press test. In addition your body fat percentage will be calculated using a three site skin fold test. Weight, height, leg length, playing position, and age will be collected.

The vertical jump test: You will be measured using a Vertec jump testing device and will be measured to the nearest half inch. Your standing reach height will be measured by standing with your feet flat on the ground and reach as high as you can with one arm and outstretched over your head. The maximum height that you can reach while maintaining a flat-footed stance will be recorded. With your preferred leg you will then be asked to perform a single leg countermovement vertical jump. The countermovement vertical jump (subjects will be allowed a squatting movement from a standing position immediately before you propel yourself upward as high as you can) will be assessed using a Vertec jump testing device (Sports Imports, Columbus, OH). You will be allowed three attempts, and the best of the three scores will be recorded. The difference between the standing reach score and the countermovement vertical jump score will be calculated and recorded as your vertical jump score.

Single-leg Horizontal Countermovement Jump: You will be asked to start at a designated starting line. Using your preferred leg, you will be asked to perform a quick countermovement squat and jump forward as far as possible with your hands placed on your hips. You will be asked to land on both legs. The distance recorded is based upon where your heel closest to the starting line (furthest back) lands.

Single-leg Lateral Countermovement Jump: You will start with the inside of your preferred leg on the edge of a designated starting line. You will perform a quick countermovement squat and jump laterally as far as possible with your hands placed on your hips. You will be asked to land on both feet with your feet together. The measurement is taken will be the distance from the lateral border of the foot of your preferred leg and the start line.

Lateral Slide Board Test: You will be asked to perform lateral slides on a low friction board while wearing nylon shoe covers. Starting on one side of the board, you will be asked to push off with your dominant leg as hard as you can, propelling yourself across the board. When reaching the other side of the board you will immediately push off the other leg to slide back to the starting point. You will continuously slide back and forth for an equivalent of five pushes with each leg. The distance between the ends of the board will be eight feet. An electrical timing device will be used to calculate the time by placing a pressure sensor on the start/finish board. A" lap time" will be taken each time you have gone down and back allowing for one push off of each leg. You will be asked to cover the distance of the slide board as quickly as possible. Power in watts will be determined for each run multiplying weight (kg) and estimates of lateral work (distance of 8 feet) divided by the corresponding time interval (seconds).

Skin-fold Measurements: Three sites for skin-fold measurements will be chosen, and measured based on your gender using the Jackson and Pollock percent body fat technique. Females will have skin-fold measurements taken at triceps brachii, suprailium, and abdominal sites. Males will have skin-fold measurements taken at the chest, triceps brachii, and subscapular sites. The sum of the respective sites will be calculated and entered into a formula to calculate body density. The formulas are provided below in which X= sum of skin folds and Y= age of the subject. Each site will be measured twice to insure reliability.

$$\text{Women: Body Density}=1.089733-0.0009245(X) + 0.0000025(X)^2 - 0.0000979(Y)$$

$$\text{Men: Body Density}=1.1125025 - 0.0013125(X) + 0.0000055(X)^2 - 0.0002440(Y)$$

Once the body density is calculated the percent of body fat will be calculated with the following formula:

$$\%\ \text{Body Fat}= (495/\ \text{body density}) - 450$$

Pro Agility (5-10-5) Test: Three lines will be marked or taped on the testing floor in increments of five yards (10 yards end to end with a line at the half-way point). Each subject will be asked to stand in a two-point stance straddling the start/finish line. You will be instructed to sprint to the right for five yards and touch a marked line on the floor with their right hand. Once you have touched the line you will then immediately sprint to the left for ten yards and touch the line on the opposing end of the course with your left hand, and then immediately sprint through the start/finish line located in the middle of the course. The course will be timed with an electronic timer using a laser trip line to start and stop the timing.

The Margaria-Kalamen power test: You will use a small flight of stairs with a six meter run up to measure lower extremity muscle power. From a six meter running start, you will be asked to sprint up the stair steps as fast as possible, with foot placement only on the third, sixth, and ninth steps. Power in watts will be determined for each run using estimates of vertical work accomplished from the third to the ninth steps divided by the corresponding time interval. You will have the opportunity to perform each test three times and the best score will be recorded.

Estimated maximum leg press: You will be asked to perform a maximum leg press lift to estimate your leg strength. You will be asked to choose a weight that you can leg press for a maximum of five repetitions. The weight and your actual number of performed repetitions will be recorded and your one repetition estimated maximum lift will be calculated and recorded. The formula used to calculate your one repetition maximum is:

$$1RM = 100 \times \text{weight lifted} / (102.78 - 2.78 \times \text{\# of repetitions performed})$$

All field tests should be able to be performed within a 90 minute time frame. You will perform each procedure one time during pre-season, one time near the mid-point of your competitive season, and one time following the week your season ends. You will be allowed an orientation time to familiarize yourself before each test.

Risks and Benefits: The benefits include contributing to the knowledge base of the changes that occur in muscle performance during a basketball season, as well as an assessment of the in-season strength and conditioning program at your university. Each of you will be granted a time of instruction and familiarization with the tests you will be performing. You will also be required to perform your normal warm-up routine that they would normally perform before their normal training session in order to reduce the risk of muscle injury, and an athletic trainer will be available to you during testing. You will not be at a greater risk for personal injury than you normally experience through your regularly scheduled weight training workouts and sport practices. These risks could include an orthopedic injury or wound due to falls occurred during the testing procedures. Some of these injuries could include contusions, scrapes, muscle strain or ligament sprain.

Voluntary Participation: Your participation is voluntary in this research project. You will not receive any financial compensation, course credit, or any other credits from your involvement in this project.

Confidentiality: All records will be kept confidential to the extent allowed by law and the University of Arkansas policy. Your individual scores will only be accessed by the researchers of this project and you will be assigned a number. The code linking your name to your number will be destroyed upon completion of this research project. The researchers of this project and your coaching staff will have access to any of the data collected from your participation throughout the data collecting time period. Coaching staff will not have access to individual performance test scores of anyone not on roster of the team they coach.

Right to Withdraw: You are free to refuse to participate in this research project or withdraw from the project at any time. Your decision to withdraw will not have any negative consequences or penalty to you.

Informed Consent: I, ________________________________, have read the description,
(Print name here)
including the purpose of the study, the procedures to be used, the potential risks, the confidentiality, as well as the option to withdraw from the study at any time. Each of these items has been explained to me by the investigator. The investigator has answered all of my questions regarding the study, and I believe I understand what is involved. My signature below indicates that I freely agree to participate in this study.

This project has been reviewed and approved by the Evangel University Human Subjects Research Review Board. The Borard believes that the research procedures adequately safeguard the subject's privacy, welfare, civil liberties, and rights.

I have read the material above, and any questions I asked have been answered to my satisfaction. I agree to participate in this activity, realizing that I may withdraw without prejudice at any time.

Subject or Authorized Representative　　　　Date

______________________________________　　　　____________________________

Signature　　　　Date

IRB Approval Letter

UNIVERSITY OF ARKANSAS

Office of Research Compliance
Institutional Review Board

November 8, 2011

MEMORANDUM

TO:	Kevin King Inza Fort
FROM:	Ro Windwalker IRB Coordinator
RE:	New Protocol Approval
IRB Protocol #:	11-10-169
Protocol Title:	*Effects of a Varsity Basketball Season on Lower Extremity Power Output in Collegiate Basketball Players*
Review Type:	☐ EXEMPT ☒ EXPEDITED ☐ FULL IRB
Approved Project Period:	Start Date: 11/07/2011 Expiration Date: 11/03/2012

Your protocol has been approved by the IRB. Protocols are approved for a maximum period of one year. If you wish to continue the project past the approved project period (see above), you must submit a request, using the form *Continuing Review for IRB Approved Projects*, prior to the expiration date. This form is available from the IRB Coordinator or on the Research Compliance website (http://vpred.uark.edu/210.php). As a courtesy, you will be sent a reminder two months in advance of that date. However, failure to receive a reminder does not negate your obligation to make the request in sufficient time for review and approval. Federal regulations prohibit retroactive approval of continuation. Failure to receive approval to continue the project prior to the expiration date will result in Termination of the protocol approval. The IRB Coordinator can give you guidance on submission times.

This protocol has been approved for 45 participants. If you wish to make *any* modifications in the approved protocol, including enrolling more than this number, you must seek approval *prior to* implementing those changes. All modifications should be requested in writing (email is acceptable) and must provide sufficient detail to assess the impact of the change.

If you have questions or need any assistance from the IRB, please contact me at 210 Administration Building, 5-2208, or irb@uark.edu.

210 Administration Building • 1 University of Arkansas • Fayetteville, AR 72701
Voice (479) 575-2208 • Fax (479) 575-3846 • Email irb@uark.edu

Appendix B

Explanation of Different Warm-Up Drills

Warm-up Motion: High Knees

Figure B1. Subjects were instructed to progress quickly through the motions with the lead leg of flexing their hip and knee bringing their hip past 90° of hip flexion with a bent knee, returning the lead leg to a neutral hip position with knee extended while bringing the trail leg into the lead leg position, and repeating the process. This process was repeated until the prescribed distance had been traveled by the subject(s). Photo by author.

Warm-up Motion: Butt Kicks

Figure B2. Subjects were instructed to quickly flex their knee to the end range of motion for active knee flexion and return the leg to a standing position as knee flexion of the opposite leg commenced. Forward momentum was allowed and the process continued until the prescribed distance was traveled. Photo by author.

Warm-up Motion: Tin Soldiers

Figure B3. Subjects were instructed to flex their hip with extended knee until maximum height of the foot was attained while reaching with the contralateral hand attempting to touch the toes of the elevated foot. Once Maximum height of the foot was achieved the subjects returned to a standing position while taking one step forward and repeated the process with the opposing leg until the prescribed distance was traveled. Photo by author.

Warm-up Motion: Carioca

Figure B4. Subjects were instructed to move in a lateral direction. The first motion in the lateral direction was to cross the trail leg posteriorly across the lead leg transferring body weight to the trail leg, followed by a reposition and transfer of weight onto the lead leg into a slightly abducted hip position, followed by a second crossover step (anterior crossover of trail leg) with a high knee motion resulting in a third step and third transfer of body weight. The process continued for the prescribed distance and repeated in the opposite direction. Photo by author.

Warm-up Motion: Lateral Slides

Figure B5. Moving in a lateral direction, the subject is asked to step laterally by abducting the hip of their lead leg while simultaneously abducting both shoulders, transfer their body weight to the lead leg, adduct the hip of their trail leg while adducting both shoulders. This process is repeated until the prescribed distance is traveled and then repeated in the opposite direction. Photo by author.

Warm-up Motion: Walking Lunges

Figure B6. In a forward motion, the subject was instructed to take an exaggerated step forward loading their body weight on the lead leg. Subjects were then instructed to flex the hip and knee of the lead leg to 90° lowering their vertical stance. Subjects then recovered to a full standing position centered on the lead leg. The opposite leg was used for the lead leg on the next step and the process was repeated until the prescribed distance traveled was obtained. Photo by author.

Appendix C

Data Collection Forms

Table C1

Margaria Kalamen

Subject	Trial 1	Trial 2	Trial 3	Best Score

Table C2

Single-Leg Horizontal Jump

Subject	Trial 1	Trial 2	Trial 3	Best Score

Table C3

Single-Leg Lateral Jump

Subject	Trial 1	Trial 2	Trial 3	Best Score

Table C4

Single-Leg Vertical Jump

Subject	Reach	Trial 1	Trial 2	Trial 3	Best Score

Table C5

Shuttle Run

Subject	Trial 1	Trial 2	Trial 3	Best Score

Table C6

Slideboard

	Trial 1					Trial 2				
Subject	Lap 1	Lap 2	Lap 3	Lap 4	Lap5	Lap 1	Lap 2	Lap 3	Lap 4	Lap 5

Table C7

Leg Press

Subject	Weight	Reps

General Information

Subject ID#	Team#	Gender	Age	Height
1	1	F	19	5’5
2	1	F	20	5’11
3	1	F	19	5’10
4	1	F	18	5’9
5	1	F	19	5’10
6	1	F	20	6’
7	1	F	18	6’2
8	1	F	21	6’1
9	1	F	19	5’7
10	1	F	19	5’9
11	1	F	22	5’10
12	1	F	21	5’7
13	1	F	19	6’1
14	1	F	22	5’9
15	1	F	19	5’9
16	1	F	20	5’11
17	2	F	18	5’7
18	2	F	22	5’10
19	2	F	20	6’1
20	2	F	18	5’9
21	2	F	22	6’2
22	2	F	18	5’10
23	2	F	18	5’10
24	2	F	19	5’4
25	2	F	21	6’2
26	2	F	21	6’
27	2	F	19	5’7
28	2	F	21	5’8
29	2	F	21	6’1
30	2	F	21	6’
31	3	M	21	6’2
32	3	M	21	6’6
33	3	M	21	6’7
34	3	M	19	6’2
35	3	M	20	6’3
36	3	M	22	6’1
37	3	M	20	6’5

38	3	M	22	5’11
39	3	M		5’11
40	3	M	21	6’1
41	3	M	23	5’11
42	3	M	19	5’10
43	3	M	21	6’5
44	3	M	18	6’5
45	4	M	24	6’2
46	4	M	19	6’1
47	4	M	25	5’8
48	4	M	20	5’10
49	4	M	18	5’9
50	4	M		
51	4	M	21	6’
52	4	M	23	6’
53	4	M	19	6’3
54	4	M	22	6’2
55	4	M	21	6’1

Team 1

	Preseason		Midseason		Postseason	
Subject ID#	BF%	Weight	BF%	Weight	BF%	Weight
1	18.27	138	12.79	137		
2	19.61	151	14.10	147	19.61	147.4
3		155	11.13	152	15.93	147.1
4	15.21	148	9.75	147		
5	10.65	122	4.37	122	10.65	123
6	19.29	157				
7	17.90	153	11.03	151		
8	22.46	156	14.20	157	20.60	163.6
9	16.61	123	12.79	124	18.92	122.4
10	14.90	140	8.53	135	14.21	136.6
11	23.71	189	22.25	182	26.58	186.6
12	18.35	146	12.59	145		
13	23.28	186	21.92	185	24.75	187.4
14	17.41	148	11.87	143		
15	19.24	153	17.36	155	18.59	155.4

16	17.65	160	11.66	152	14.95	150.2

Team 2

	Preseason		Midseason		Postseason	
Subject ID#	BF%	Weight	BF%	Weight	BF%	Weight
17	25.560	150	15.55	136.2	14.86	138.2
18	25.168	153	19.37	147.8		
19		161				
20	24.412	149	22.03	149.2	24.70	153.2
21	31.004	193	31.49	189	29.51	191.2
22	28.814	170	24.70	168.2	25.28	168
23	26.950	181				
24	17.277	139	18.27	133.8	16.94	134.4
25	25.124	185	22.46	175.4		
26	28.690	174	23.66	172.8	23.96	170.2
27	18.267	127			15.59	119.2
28		139		131.2	24.25	132.2
29		174		166		
30	30.958	200	24.55	201		

Team 3

	Preseason		Midseason		Postseason	
Subject ID#	BF%	Weight	BF%	Weight	BF%	Weight
31	5.053	198	5.052	196.4	4.575	201.2
32	14.982	216	11.343	218.6	13.001	219.8
33	7.839	213			6.462	210.4
34	6.719	172	5.322	165		
35	4.473	162	3.993	162.2	3.021	163.7
36	9.286	189	8.394	183	11.448	180.9
37	3.993	196	5.894	199.8	4.950	202.6
38	6.565	178	4.677	178.6	5.628	177.7
39	8.306	195	11.865	201.6	9.980	208.8
40	5.996		5.526	175.4	5.996	180.5
41	3.325	168				
42	8.974	176	9.850	175.6	9.414	180.7
43	5.996	204	5.996	199.2	6.462	201.2

44	5.220	186	5.689	181.8	5.220	185.9

Team 4

	Preseason		Midseason		Postseason	
Subject ID#	BF%	Weight	BF%	Weight	BF%	Weight
45	5.8332148	191	9.934800758	188.1	10.37154309	191.6
46	3.8912926	201	6.71938008	201	5.321675565	194
47	4.983099	155	4.983098986	153.6	4.501423416	150.6
48	4.9504816	159	6.359788526	157		
49	9.310005	165	14.66285893	164	13.08835024	159.8
50						
51	4.5753004	162	6.925115512	160	6.925115512	163.6
52	4.7791083	176	4.297864295	167.8	6.201226214	171.8
53			11.13365284	217.2	10.7096138	220
54	11.448323	172	7.942598052	170.4		
55	5.5261534	164	5.526153413	160	6.462471177	162.4

Margaria

Subject ID#	Preseason	Midseason	Postseason
1	0.61		
2	0.76	0.50	0.60
3	0.58	0.59	0.58
4	0.52	0.56	
5	0.64	0.65	0.62
6	0.63		
7	0.69	0.69	
8	0.58	0.65	0.70
9	0.60	0.59	0.55
10	0.62	0.60	0.71
11	0.70	0.74	0.72
12	0.82	0.69	
13	0.70	0.68	0.74
14	0.72	0.75	

15	0.65	0.66	0.58
16	0.61	0.62	0.59
17	0.65	0.54	0.58
18	0.74	0.69	
19	0.69		
20	0.68	0.62	0.67
21	0.82	0.72	0.78
22	0.65	0.64	0.62
23	0.86		
24	0.60	0.59	0.65
25	0.69	0.61	
26	0.85	0.62	0.62
27	0.56		0.56
28		0.70	0.71
29		0.84	
30	0.72	0.57	
31		0.51	0.46
32	0.62	0.47	0.47
33	0.62		0.53
34	0.49		
35	0.58	0.49	0.47
36	0.58	0.52	0.44
37	0.49	0.41	0.44
38	0.49	0.39	0.44
39	0.54	0.48	0.48
40		0.44	0.45
41	0.48		
42	0.52	0.45	0.45
43	0.60	0.50	0.55
44	0.62	0.51	0.52
45	0.39	0.54	0.45
46	0.41	0.51	0.42
47	0.38	0.48	0.47
48	0.45	0.57	
49	0.41	0.54	0.44
50			
51	0.39	0.53	0.45
52	0.45	0.55	0.44
53	0.51		0.54
54	0.47	0.53	
55	0.45	0.45	0.47

Shuttle

Subject ID#	Preseason	Midseason	Postseason
1	4.60	4.55	
2	4.91	4.80	5.13
3	4.63	4.60	4.85
4	4.47	4.37	
5	4.90	4.62	5.00
6	4.91		
7	4.97	4.81	
8	5.02	5.04	5.27
9	4.66	4.60	4.81
10	4.79	4.80	5.04
11	5.12	5.22	5.41
12	4.86	4.91	
13	4.85	4.72	4.96
14	4.77	4.84	
15	4.65	4.76	5.19
16	4.71	4.74	5.13
17	5.02	5.15	4.93
18	5.26	5.54	5.46
19	5.08		
20	5.10	5.10	5.31
21	5.56	5.36	5.47
22	5.02	5.09	5.07
23	5.11		
24	4.84	4.96	5.06
25	5.37	5.39	5.21
26	5.05	5.30	5.14
27	4.66		4.86
28		5.31	5.34
29		5.17	
30	5.18	5.06	
31		4.28	4.15
32	4.45	4.40	4.43
33	4.30		4.32
34	4.44	4.60	
35	4.30	4.41	4.54
36	4.62	4.44	4.31

37	4.41	4.56	4.14
38	4.32	4.18	4.05
39	4.54	4.40	4.52
40		4.43	4.41
41	4.08		
42	4.48	4.33	4.29
43	4.39	4.38	4.44
44	4.41	4.31	4.34
45	4.30	4.36	4.18
46	4.42	4.42	4.09
47	4.36	4.26	4.19
48	4.32	4.86	
49	4.55	4.57	4.33
50	4.58		
51	4.01	4.01	4.57
52	4.16	4.54	4.23
53	4.56	5.83	4.59
54	4.08	4.41	
55	4.60	5.30	4.42

Vertical Jump

Subject ID#	Preseason	Midseason	Postseason
1	6.50	5.50	
2	9.00	8.50	9.00
3	8.00	8.50	10.50
4	10.50	10.00	
5	6.50	8.00	6.50
6	10.50		
7	15.00	14.50	
8	11.00	10.50	12.00
9	2.50	1.50	2.50
10	9.00	8.00	7.50
11	7.50	7.50	9.00
12	9.50	8.00	
13	13.50	13.50	13.50

14	5.00	5.50	
15	7.00	5.50	6.00
16	10.00	10.00	9.50
17	3.00	3.00	4.50
18	6.00	5.50	8.00
19	9.00		
20	4.00	7.50	7.00
21	12.00	10.00	11.00
22	4.00	5.50	5.50
23	6.00		
24	3.50	4.00	4.50
25	12.00	11.00	14.50
26	8.00	8.00	10.50
27	8.50		6.00
28		1.50	14.00
29		7.00	
30	13.50	11.00	
31	5.00	8.50	7.50
32	19.50	20.50	21.50
33	12.00		12.50
34	20.50	20.50	
35	18.00	19.00	20.50
36	18.00	18.00	18.50
37	21.00	11.50	5.50
38	15.50	17.50	17.00
39	17.50	16.00	15.00
40		2.50	13.50
41	15.50		
42	13.00	13.00	13.00
43	5.50	5.00	5.00
44	6.50	7.50	6.00
45	18	117	108.5
46	18.5	119.5	113
47	12.5	108.5	102.5
48	13.5	107.5	
49	10.5	106.5	100
50	20.5		
51	19	113	111
52	18	112.5	111
53	21.5	113.5	110
54	15	113.5	
55	18.5	113	106

Horizontal Jump

Subject ID#	Preseason	Midseason	Postseason
1	1.82	2.12	
2	1.81	1.96	1.75
3	1.85	2.04	1.82
4	2.00	2.06	
5	1.70	1.72	1.75
6	2.00		
7	2.02	1.92	
8	1.74	1.79	1.62
9	1.75	1.83	1.77
10	1.84	2.04	1.78
11	1.66	1.81	1.72
12	1.78	1.85	
13	1.89	1.86	1.82
14	1.57	1.70	
15	1.87	2.06	1.92
16	1.80	2.08	1.91
17	1.86	1.92	1.76
18	1.57	1.58	1.40
19	1.74		
20	1.82	1.78	1.57
21	1.50	1.66	1.32
22	1.65	1.71	1.62
23	1.62		
24	1.80	1.72	1.68
25	1.65	1.85	1.80
26	1.69	1.83	1.65
27	1.91		1.68
28		1.73	1.67
29		1.68	
30	1.80	1.91	
31	2.26	2.35	2.48
32	2.26	2.24	2.23
33	2.42		2.32
34	2.38	2.38	
35	2.15	2.13	2.02
36	2.21	2.13	2.11

37	2.37	2.30	2.21
38	2.30	2.37	2.34
39	2.32	2.36	2.35
40		2.19	2.13
41	2.35		
42	2.19	2.32	2.16
43	2.22	2.25	2.12
44	2.38	2.47	2.32
45	2.30	2.17	2.21
46	2.54	2.42	2.44
47	2.22	2.23	2.21
48	2.27	2.06	
49	2.02	2.05	2.05
50	2.10		
51	2.33	2.32	2.41
52	2.35	2.23	2.43
53	2.17	1.62	2.17
54	2.14	2.12	
55	2.02	1.86	2.06

Lateral Jump

Subject ID#	Preseason	Midseason	Postseason
1	1.82	1.76	
2	1.65	1.72	1.68
3	1.81	1.82	1.75
4	1.82	1.89	
5	1.75	1.79	1.78
6	1.80		
7	1.73	1.77	
8	1.78	1.75	1.77
9	1.64	1.74	1.74
10	2.02	1.94	1.89
11	1.68	1.71	1.52
12	1.58	1.59	
13	1.72	1.81	1.78

14	1.68	1.65	
15	1.76	1.73	1.77
16	1.76	1.78	1.78
17	1.87	1.87	1.77
18	1.68	1.64	1.57
19	1.86		
20	1.78	1.78	1.77
21	1.76	1.61	1.54
22	1.74	1.67	1.67
23	1.65		
24	1.74	1.57	1.52
25	1.69	1.78	1.65
26	1.77	1.83	1.62
27	1.78		1.79
28		1.55	1.50
29		1.77	
30	2.11	1.92	
31	1.56	2.28	2.11
32	2.10		2.06
33	2.38		2.13
34	2.22	2.05	
35	2.03	1.98	1.87
36	2.08		1.82
37	2.02	2.07	1.98
38	2.07	2.10	2.04
39	2.16	2.15	2.14
40		2.05	1.93
41	2.33		
42	2.17	2.08	2.08
43	2.20	2.07	2.09
44	2.08	2.23	2.13
45	2.21	2.07	2.05
46	2.31	2.35	2.35
47	2.04	2.13	2.26
48	1.98	1.87	
49	1.87	1.93	1.96
50			
51	2.27	2.27	2.05
52	2.27	2.14	2.22
53	2.04	1.63	2.08
54		1.95	
55	1.83	1.75	1.90

Leg press

Subject ID#	Preseason	Midseason	Postseason
1	367.47		
2	275.89	239.98	258.07
3	392.89		290.00
4	354.33	341.35	
5	196.13	248.93	223.02
6	296.35		
7	223.02	248.93	
8	248.93	230.00	210.27
9	320.15	265.12	246.84
10	300.60	283.41	281.20
11	343.76	340.66	310.00
12	250.00	266.68	
13	250.00	266.68	266.68
14	278.72	281.20	
15	270.00	270.00	270.00
16	300.60	300.60	305.45
17	589.33	376.79	402.80
18	283.88		266.66
19	305.45		
20	248.30		
21	293.35	303.48	315.00
22	403.30	385.00	342.19
23	325.98		
24	498.57	455.00	428.21
25	275.00	275.00	258.81
26	376.79	365.00	376.79
27	382.74		296.45
28			
29		266.71	
30	974.80	634.54	
31	834.20	418.08	446.94
32	585.00	585.00	624.04
33	624.04		546.26
34	603.89		
35	432.03	438.72	438.72
36	495.00	495.00	495.00

37	585.00	645.58	603.89
38	603.89	752.72	800.13
39	789.70	899.39	1086.99
40		485.36	539.35
41	603.89		
42	696.79	800.13	748.41
43	546.26	601.44	622.94
44	534.82	519.95	528.47
45	450.495	411.8494	388.83
46	755.4048	690.8672	539.60
47	580.9549	507.8357	557.03
48	653.6615	479.6	
49	522.8036	522.8036	448.06
50	539.604		
51	361.3861	361.3861	361.39
52	649.505	526.4718	557.03
53	490.099		400.99
54	435.6	481.9928	
55	388.8283	350.4255	361.39