EFFECTS OF AN EIGHT WEEK STRENGTH INTERVENTION ON MIXED MARTIAL ARTS TECHNIQUES

by

CLAY HARDEN WALKER

(Under the Direction of Michael Horvat)

ABSTRACT

The research for this dissertation investigated the relationships between power, strength, components of the NSCA performance index and peak power in 3 commonly used mixed martial arts (MMA) techniques: cross, rear knee and the double leg takedown. Two studies were completed. In each study, participants' peak power was measured in the 3 MMA techniques. In study 1, participants performed an eight week strength training intervention and was tested in peak power in each technique, strength in the upper body (bench press) and lower body (deadlift) and power in the upper body (60% of 1RM bench press) and lower body (vertical jump) at week 1, week 4, and week 8. Strength and power were found to increase as a result of the strength training intervention. Peak power also increased in each MMA technique. The strength and power assessments that were responsible for each increase in peak power differed for each technique. The peak power of the cross increased as a result of an increase in the deadlift ($p=0.05$) and the tandem of the increase in deadlift and bench press strength ($p=0.09$). The peak power of the rear knee increased as a result of the increase in deadlift strength ($p=0.002$), the tandem of deadlift and bench press strength ($p=0.06$) and increase in vertical jump ($p=0.04$). The peak power of the double leg takedown increased as a result of an increase in the tandem of

vertical jump and bench press for power. In study 2, the components of the NSCA performance index were used to try and predict the peak power in the MMA techniques. Only the vertical jump was found to be significant ($p=0.09$) in predicting the peak power of the cross. SAS 9.5 (Cary, NC) was used to analyze all data. The results of the investigation led us to believe that the components of the NSCA performance index were designed for more lateral and longitudinal sports such as football and soccer; therefore, another type of performance index consisting of shorter and more compact movements would need to be developed in order to predict performance in MMA.

INDEX WORDS: mixed martial arts, MMA, peak power, strength, performance index

EFFECTS OF AN EIGHT WEEK STRENGTH INTERVENTION ON MIXED MARTIAL ARTS TECHNIQUES

by

CLAY WALKER

BS, The University of Georgia, 2001

Med, The University of Georgia, 2003

A Dissertation Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

DOCTOR OF PHILOSOPHY

ATHENS, GEORGIA

2011

EFFECTS OF AN EIGHT WEEK STRENGTH TRAINING INTERVENTION ON MIXED MARTIAL ARTS TECHNIQUES

by

CLAY WALKER

Major Professor:	Michael Horvat
Committee:	Bryan Mccullick Jonathan Templin

Electronic Version Approved:

Maureen Grasso
Dean of the Graduate School
The University of Georgia
August 2011

DEDICATION

I dedicate this work to my family and friends who have supported me through this journey. Thank you for helping me understand what life is all about and how to enjoy the little things life gives us all. I would like to give a special thanks to my mom, dad, sister and brother for always being there for me no matter what I was going through. You will always have my unconditional love.

ACKNOWLEDGEMENTS

I would like to express my eternal gratitude to the owners, coaches, and athletes at The HardCore Gym in Athens, GA, especially Adam and Rory Singer. I want to thank all those who had a hand in helping me finish this project: Rex Bradberry, Keith Gray, Norm Leonard, Dave Van Halanger and Sorinex Equipment. I would also like to thank my committee members, Bryan Mccullick and Jonathan Templin, and in addition to Michael Ferrara for there guidance through this journey. Finally, I thank Michael Horvat for believing in me and allowing me fulfill a dream.

TABLE OF CONTENTS

Page

LIST OF TABLES

Page

LIST OF FIGURES

Page

CHAPTER 1

INTRODUCTION

The origins of mixed martial arts (MMA) have been traced to the ancient Greek sport of pankration (Kim, S., Greenwell, T.C., Andrew, D.P.S., Lee, J., Mahony, D.F. 2008). The literal translation of pankration is "all powers" and was a mixture of Hellenic boxing and wrestling involving close quarters combat between two participants. The influence of pankration into the Greek ethos of strengthening the mind, body and spirit lead to its inclusion, and eventual dominance, into the Olympic Games in 649 B.C. Modern MMA is a summation of various fighting styles including boxing, wrestling, Muay Thai, kickboxing, judo and Brazilian Jui Jitsu and has hit main stream popularity over the past ten years (Kim et al. 2008). The recent rise in MMA popularity has lead to several major organizations including the Ultimate Fighting Championship (UFC), MMA's biggest arena. The most talented, popular, and successful fighters make thousands of dollars for undercard matches and up to several million dollars for a main event match.

MMA has become as popular as many of the other main stream sports. In fact, MMA audience has grown to match that of the three major sporting events in the United States: baseball, basketball, and football. For example, the UFC Light Heavyweight Championship Fight in September 2007 drew 5.6 million viewers; more than any televised sporting event that weekend including the Oregon vs. Michigan football game, the Virginia Tech vs. LSU football game, the U.S. Open women's final and a NASCAR Nextel Cup race. A potential reason for the current growth in popularity and participation in MMA could be the combination of skill and

knowledge needed by the sports participants. This skill and knowledge is utilized in very unpredictable combinations of very short bursts of high intensity engagement. The unpredictability of MMA requires an MMA athlete to train in many disciplines of martial arts. For example, even a novice MMA athlete must prepare for multiple aspects of physical combats that include striking, takedowns and the defense of takedowns, grappling, clinching, conditioning/muscle endurance, and strength and power(Amtmann, J., 2004). Often an MMA fighter accomplishes a mastery of their various movements by being trained in kickboxing and Muay Thai, as well as wrestling and Brazilian Jui Jitsu.

It is apparent that successful MMA athletes require a large skill and knowledge base in many diverse styles of martial arts. One key element for sustained high performance of these athletes is an effective strength and conditioning program to develop overall fitness (Amtmann, J.A., Amtmann, K.A., Spath, W.K. 2008). Primary benefits of a strength and conditioning program are the decrease in injuries and ability improve performance. According to Amtmann (2010), no other sport requires the volume of training required to excel in mixed martial arts. However, the high volume and intensity of training required exacerbates the amount of acute injuries in MMA. Therefore, the importance of strength and conditioning cannot be underrated and is a proven factor that helps prevent injuries through not only increasing muscular strength and endurance but also increasing joint integrity, fat-free mass, resting metabolic rate, bone mass, glucose tolerance, and increasing musculotendinous integrity (Baechle et al. 2008; Siff, M. 2000).

The other benefit and probably most important aspect of an effective strength and conditioning program is its ability to improve performance. Performance requirements for athletes and a specific sport are variable and MMA requires high levels of function in order to

execute the specific movements in the sport. For example, the primary objective is the submission of one's opponent through various takedowns and locks or even by knockout blows using the hands, knees, and feet. In order to accomplish a submission or knockout, the components of power and strength must be highly developed. A lackluster blow is easily brushed aside and does not punish the opponent. The more strength and/or speed the participant ultimately possesses, the more forceful the participant can punch, kick, grapple or knee. This forces the opponent into submission and increases the chances for a successful performance and victory. The stronger and more powerful participants are more durable in maintaining posture to absorb blows and generate force in squeezing submission techniques, clinching for knees, takedowns and boxing. Strength and power need to be developed; therefore, a specific program designed to improve or increase these key aspects of MMA is imperative to the optimal health and performance of these athletes.

Development of Power and Strength

Power, as defined in sport, is the product of force and velocity; or, it can also be defined as the rate of performing work (Komi, P.V. 2004). Maximum power, or peak power, is the maximum amount of work a muscle can do per unit time (Jandacka, D., Vaverka, F. 2008). Since power is a result of force and velocity, both of these principles become a factor when determining peak power and are dependent upon one another. The force-velocity curve is used to describe the relationship between these two components and the amount of possible power. At high rates of force, velocity is very low and in contrast low levels of force produce a high velocity output. Everything under the curve represents the amount of possible power for a given force and velocity (Siff, M., 2000). Komi (2004) has shown that there are various loads that an athlete can train with to increase muscle power in different movements. Those loads differ from

10% to 70% of a given one repetition maximum. Stated differently, there are a drastic number of different percentages that can be used to determine peak power in multi-joint movements. These loads determine the amount of velocity and force needed to complete a movement; in turn, that movement produces a given power. It is a goal of a well established strength and conditioning program for MMA athletes to not only increase speed but also force, therefore making the force velocity curve larger for each athlete.

In order to determine the amount of power output in a certain movement several factors should be considered. Power movements are fueled by the body's non-oxidative (anaerobic) system and use two phosphates as energy: 1) adenosine triphosphate (ATP) and 2) creatine phosphate (CP). The other system used as energy is glycolysis which breaks down carbohydrates stored in the muscle into glycogen blood glucose (Baechle, Earle, 2008). In addition, neuromuscular factors contribute to the amount of force produced. For example, fast twitch, or type II, muscle fibers are the largest of the two muscle types and are recruited for maximal power output. Other neuromuscular factors that affect power output are length of muscle fibers, muscle cross sectional area, muscle mass, type of movement, direction of muscle contraction, and metabolism (Jandacka, D., Vaverka, F. 2008). Both factors provide the athlete with the ability to generate high power levels. An athlete that has maximally trained both systems is considered to in shape. For example, an American football player at the end of summer training should be able to utilize both systems at a maximum as well as a MMA athlete when he steps into the ring. The goal of the strength and conditioning coach is for the athlete to maximize and peak the conditioning of the athlete at the time of the competition.

Strength is another important component of training programs in MMA. Strength is defined as the ability of a given muscle or group of muscles to generate muscular force under

specific conditions (Siff, M. 2000). It is a result of muscular action initiated and orchestrated by electrical processes in the nervous system of the body. Physiologically, strength is a primary function of one of the appropriate muscles powerfully contracting by effective nervous stimulation. As a result of neuromuscular stimulation, the nervous system produces two basic adaptive and interrelated effects on the body. These effects are functional muscular action and hypertrophy (Siff, M. 2000). Therefore, a second and equally important goal of a strength and conditioning program in MMA is to increase strength which would allow the athlete to perform techniques with more force and consequently more power.

Biomechanically, there are many factors that influence human strength 1) neural control 2) cross sectional area 3) angle of pennation 4) muscle length 5) joint angle 6) contraction velocity and 7) strength to mass ratio (Baechle et al. 2008; Siff, M. 2000). Neural control determines which and how many motor units are involved in a muscle contraction and the rate at which these motor units are fired; the more motor units activated the more strength produced (Baechle et al. 2008). Muscle cross sectional area describes the volume of the muscle; the more cross sectional area a muscle has the more force it should be able to produce (Baechle et al.2008; Siff, M. 2000). The arrangement of muscle fibers determines the angle of pennation; the longer the angle of pennation the more strength produced as the muscle shortens. Muscles at resting length have more cross bridge sites available for activation which enables greater force potential (Baechle et al. 2008). Joint angle affects the torque of the movement; therefore, a larger torque value gives a greater tendency for an applied force to rotate the limb or body part about the joint (Baechle et al. 2008). Muscle contraction velocity is the amount of force that a muscle can produce declines with the increase in velocity. In terms of joint angle velocity, there are three types of muscle action. In the concentric muscle action, the muscle shortens because the

contractile force is greater than the resistive force. During an eccentric muscle action the muscle lengthens because the contractile force is less than the resistive force. During the isometric muscle action the muscle length does not change because the contractile force is equal to the resistive force (Baechle et al. 2008). To explain the strength to mass ratio, the force a body produces has to be more than the mass of the body for strength to be adequate to move. This also affects the human body's ability to accelerate. For instance, if a person increases his or her body mass by 30% but only increased the strength by 20%, that person's ability to accelerate and produce force has decreased. Another factor in relation to the strength to mass ratio is the body size. Smaller athletes are stronger, pound for pound, than larger athletes, because the smaller athlete has a higher strength to mass ratio than does the larger athlete (Baechle et al. 2008; Siff, M. 2000).There are many factors that affect strength, together physiological and neuromuscular adaptations are the cornerstones that determine the amount of strength a person can produce.

In summary, MMA is a rapidly growing sport that is capable of surpassing audience membership greater than many of the other major sports. Participants in MMA utilize numerous fighting skills and knowledge that allow them to win a fight nearly infinite ways. A well designed strength and conditioning program can assist participants in MMA by increasing performance and decreasing potential rates of injury. An effective strength and conditioning program would allow the athlete to practice longer and harder by creating more power and strength that will allow a better performance and can help in preventing the body from breaking down physically. A participant already encompassing the skills necessary to be a dominant performer may positively enhance his or her chances of victory by having a more powerful punch, kick, or takedown and a stronger clinch and defense.

Statement of Problem

MMA requires a complex combination of numerous fighting skills and knowledge; while, strength and conditioning provides the foundational aspects for power and strength needed for optimal performance. Because the modern version of the sport is still in its infancy, a scarcity of information is available on training programs that directly impact both power and strength outputs in MMA athletes. There is pertinent information that can come from the answers of several fundamental questions in relation to MMA and a strength and conditioning program: does power increase, does strength increase, and more importantly, what does an increase in power and/or strength do to the performance aspect? Further, can specific outcome measures in indices be used to correlate to gains in muscle power and strength to performance power within field based and training settings? The answers to these questions could provide the solutions for developing a safe and effective strength and conditioning program for participants in MMA.

Specific Aims

The specific aims of this study are to:

1) Determine if an 8 week strength and conditioning intervention increases peak power in 3 common mixed martial arts techniques: cross, rear knee, and double leg takedown.
2) Determine if there is a relationship between the NSCA Performance Index and peak power measures given by the Tendo Power and Speed Analyzer.

Hypotheses

This study is designed to determine the effect of a strength and conditioning intervention on peak power outputs in MMA participants. Specific interests in this study are the development of strength and power performance. The research hypotheses for this study are:

1) Following an 8 week training intervention, a significant increase in power in the lower body and upper body will result in a significant increase in peak power on three mixed martial arts techniques.
2) Following an 8 week training intervention, a significant increase in strength in the lower body and upper body will result in a significant increase in peak power on three mixed martial arts techniques.
3) The peak power output in all three MMA techniques demonstrate a strong positive correlation with the performance index developed by the National Strength and Conditioning Association.

Significance of the Study

The intent of this study is to determine outcomes in power and strength that are specific to several common MMA techniques. To my knowledge this a novel study that will provide quantitative data identifying the relationships between power and strength in common techniques used in mixed martial arts. It will also be the first to attempt to use a performance index to help relate peak power to other common functional test measures.

Limitations of the Study

The following are limitations of the study:

1. The findings of this study are not comparable to any other study other than studies used to determine peak power in other sports. This is a novel study in relation to the population being observed. To my knowledge, this will be the first study to explain MMA athleticism in terms of strength and conditioning to influence power and strength.

2. The findings from this study will only be comparable to the other studies utilizing the specific equipment and methods used in this study.
3. The findings in this study will only be comparable to other studies utilizing mixed martial artists interested in increasing power, strength and peak power.
4. The findings in this study will only be comparable to other studies utilizing mixed martial artists and assessment tools to determine performance potential as compared to findings in performance measured by different strength and power assessments.

Delimitations of the Study

This study is delimited to 30 mixed martial artists. They have participated in the sport for two years and have been in the advanced class at the HardCore Gym for at least 3 months.

Definition of Terms

The following terms are definitions relevant to this investigation.

Power – is a product of force and velocity (P=F x V) (Baechle et al. 2008)

Peak Power – the maximum amount of work a muscle can do per unit time (Siff, M. 2000)

Force – is the product of mass and acceleration (Baechle et al. 2008)

Velocity – distance over time (m/s) (Jandacka, D., Vaverka, F. 2008; Komi, P.V. 2004)

Strength – is the ability of the body to produce force (Baechle et al. 2008; Komi, P.V. 2004; Siff, M. 2000)

Tendo Power and Speed Analyzer – this is referred to as the Tendo Unit throughout this study. A mechanical device used to retrieve data by calculating muscle power and velocity in specific movements (TENDO Power and Speed Analyzer) (TENDO PSA310).

NSCA Performance Index – a scoring system based on results of three tests, vertical jump, pro-agility shuttle and the 10 yard dash, that give us an index of points after the three scores have

been calculated. This scoring system is designed to predict and test athletic performance, that is, the ability to respond effectively to various physical challenges. It also uses gender and body weight as variables in the index.

References

Amtmann, J. (2010). High intensity training and the mixed martial artist. In J.E. Warnick (Ed.), *Advancements in the Scientific Study of Combative Sports.* (pp.13-39). © 2010 Nova Science Publishers, Inc.

Amtmann, J.A., Amtmann, K.A., Spath, W.K. (2008).Lactate and rate of perceived exertion responses of athletes training for and competing in a mixed martial arts event. *Journal of Strength and Conditioning Research*, 22(2), 645-647.

Amtmann, J.A. (2004). Self-reported training methods of mixed martial artists at a regional reality fighting event. *Journal of Strength and Conditioning Research*, 18(1), 194-196.

Baechle, T.R., Earle, R.W. (2008). *Essentials of Strength Training and Conditioning,* 3rd Ed. Champaign, IL: Human Kinetics.

Bledsoe, G.H., Hsu, E.B., Grabowski, J.G., Brill, J.D., Li, G. (2006). Incidence of injury in professional mixed martial arts competitions. *Journal of Sports Science and Medicine,* CSSI, 136-142.

Jandacka, D., Vaverka, F. (2008). A regression model to determine load for maximum power output. *Sports Biomechanics*, 7(3), 361-371.

Kim, S., Greenwell, T.C., Andrew, D.P.S., Lee, J., Mahony, D.F. (2008). An analysis of spectator motives in an individual combat sport: A study of mixed martial arts fans. *Sport Marketing Quarterly*, 17, 109-119.

Komi, P.V. (Ed.). (2004). *Strength and Power in Sport*. Malden, MA: Blackwell Science, Inc.

Siff, M.C. (2000). *Supertraining*, 5th Ed. Denver, CO: Supertraining Institute.

CHAPTER 2

REVIEW OF LITERATURE

This chapter presents a review of the literature related to the study of the effects of an 8 week strength and conditioning intervention on peak power in three commonly used techniques in mixed martial arts (MMA). It also presents a review of literature on the relationship between power and the vertical jump, sprint times, and agility. It will conclude with literature related to the Tendo Power and Speed Analyzer and components of the NSCA Performance Index along with a summary of the literature. Research findings under the following categories will be discussed: (a) current training methods used in MMA, (b) general aspects of increasing power and strength, (c) complex training, (d) relationship between power and vertical jump, sprint times and agility and their use as a performance index, (e) Tendo Power and Speed Analyzer and NSCA Performance Index, (f) summary of the literature review.

Current Training Methods in MMA

Strength and conditioning coaches often rely on research regarding the most effective method to facilitate training. In this case, no scientific studies were evident that included MMA athletes as participants in a research study. In contrast the literature includes information from strength and conditioning coaches concerning various methods of training MMA athletes, although they have not been empirically tested (Amtmann, J. 2004; Turner, A.N. 2009; Rooney, M. 2008 and 2010; Jamieson, J. 2009; and La Bounty, P., Campbell, B.I., Galvan, E., Cooke, M., Antonio, J. 2011). Most of these publications are based on scientific training principles that are

used with MMA. While definitive research on training interventions in this population is lacking, it is apparent that most program designs are based on research performed in other sports.

Amtmann (2004) attempted to identify the different training methods of mixed martial artists at by surveying 28 MMA athletes about their overall training procedures. It was found that twenty-five fighters participated in some type of strength and conditioning in addition to their fight specific training. Only 8 of these athletes used some type of Olympic lift, such as power cleans or the hang power clean, as part of their regular training method while the rest used conventional fight specific training in combination with some type of high intensity training (HIT). The frequency of strength and conditioning sessions ranged from 7 sessions per week to only 1 session and demonstrated an inconsistency in training methods.

In a later publication, Amtmann (2010) proposed high intensity training (HIT) that allows for metabolic conditioning as a way to train the MMA athlete. Metabolic conditioning refers to the exercises intended to increase the storage and delivery of energy for any activity (Glassman, G. 2003). HIT training stresses the muscle to complete failure to achieve an overload stimulus greater than the muscle usually experiences. An example of HIT training would be setting up a circuit that included three exercises and performing those exercises as an individual set until failure is reached at each exercise. Amtmann (2010) advocates that training through HIT programs is beneficial and effective for MMA athletes who wish to improve performance and occurs through practicing a skill so that the athlete becomes more efficient in that specific skill.

More recently Turner (2009) proposed a strength and conditioning program for Muay Thai athletes based on other types of martial arts as well as general strength and conditioning research. Most participants in martial arts tend to train for a competition through skill training and sparing sessions and are concerned about reducing flexibility and body mass. Turner (2009)

proposes increasing strength and power in these athletes through combination training, which maximizes time spent in the gym by combining strength exercises and speed/power exercises (Olympic exercise and plyometric) to achieve maximum results. The program calls for progressive loading in all exercises to ensure safety and proper gains throughout the intervention.

In terms of strength and conditioning in kickboxing, Buse and Santana (2008) proposed a method of training called interval training. This type of training involves high to maximal intensity efforts in short durations with incomplete recovery in between each set. They also suggest that a kickboxer should participate in weight lifting, Olympic lifting and plyometric exercises to enhance strength and power in techniques used during a kickboxing match. They also suggested that strength and power enhancement sessions should be limited to 2 sessions each week and that the two training sessions not be combined, with strength training performed on one day and power training performed on the other.

From Rooney's (2008) popular literature proposes different exercises an MMA athlete can use to train different parts of the body in his book on Training for Warriors. This includes all the major muscle groups and exercises that should be performed to enhance the strength and power of that muscle group. In his second publication, Ultimate Warrior Workouts (2010), he described the training for individual martial arts that makes up MMA. An important concept in his work is the specificity of training to specific movements in each discipline.

Another publication by Jamieson (2009), Ultimate MMA Conditioning, examines the principles of strength and condition as it relates to the sport of MMA. Throughout the book, Jamison (2009) describes the role of strength and conditioning in the sport: as a specific physical preparation that increases the potential of muscle work. Training in strength and conditioning as well as technical and tactical preparations used to increase the speed of movement skill and

technique, therefore increasing overall performance. A description on the energy system development, the types of energy used in MMA, and how to increase the production of each energy system are also included with a recommendation that adding strength and conditioning training workouts to the repertoire of a MMA athlete enhances competition by using the energy needed to perform the tasks necessary during an MMA event. The information is presented in a logical and scientific approach to increasing the performance of an MMA athlete. The progression from low volume to strength and power training and high volume to fight specific and energy system training is recommended with the cautions to overtraining.

Recently, La Bounty et al. (2011) examined the considerations of strength and conditioning for mixed martial arts. From his knowledge of the sport of MMA, La Bounty was able to propose a strength and conditioning method for training the MMA athlete including: a) knowledge of the sport, b) understanding the nature of the sport and the amount of time spent on preparation, c) the fear of overtraining these athletes because of the amount of time and energy spent on training the sport specific skills needed by each athlete and d) interval training, namely (HIT) training which has the benefit of increasing Vo_2 peak and increase oxidative capacity in skeletal muscle faster than more traditional high-volume endurance training. He proposed that when performing HIT, the duration of the exercise interval is dependent on the intensity, albeit a few seconds up to several minutes. Also discussed is the development of power and speed for MMA. By increasing strength, power is also increased since strength is a major contributing factor of power. Increasing strength and power through a periodized strength training program using a 3-5 repetition scheme for each exercise is proposed, as is increases in speed by using ballistic movements and plyometrics. Ballistic movements as well as plyometric movements (ex. box jumps and hurdle bounds) should be used to increase speed of movement relative to the

movements used in the sport of MMA. The authors also consider nontraditional exercises, periodization, and recovery techniques to help the MMA athlete improve performance (La Bounty et al. 2011).

After an extensive literature search examining the current trends of strength and conditioning for MMA athletes, the importance of examining this population for scientific research in the field of strength and conditioning becomes obvious. There is a lack of scientific evidence that is specific to MMA training. In this context, strength and conditioning specialists require specific based data in order to develop interactive programs designed to train an MMA athlete to the best of his abilities. Currently the science behind training MMA athletes is being achieved from other sports and is not specific to mixed martial artists. In order to meet the specific needs of MMA, the proper way of training needs to be investigated in the medium of MMA and is a major factor of this study.

General Aspects of Increasing Power and Strength

The ability of the neuromuscular system to produce maximal power output appears to be crucial in many sports that require optimal combinations of muscle strength and speed to maximize athletic performance. The combination of these two factors, muscle strength and speed, are important factors in examining the techniques of MMA. The combination of this strength and speed is referred to as power and represents the amount of work a muscle can produce per unit of time. Power can be increased by way of increasing strength and/or increasing the speed of movement and has been studied extensively (Siff, M. 2000; Komi, P.V. 2004; Jandacka, D., Vaverka, F. 2008). An important component of these studies is the relevance and purpose of increasing power to facilitate performance in MMA. Increasing strength through a periodized strength and conditioning program has been shown to increase

power (Fleck, S.J. 1999). Plyometric exercises are another way of increasing power through increasing speed (Ludin, P., Berg, W. 1991). Plyometric training is used to improve power output and increase explosiveness by training the muscles to do more work in a shorter amount of time and is accomplished by optimizing the stretch-shortening cycle, which occurs when the active muscle switches from a rapid eccentric muscle action to a rapid concentric muscle action (Luebbers, P.E., Potteiger, J.A., Hulver, M.W., Thyfault, J.P., Carper, M.J., Lockwood, R. H. 2003). Other studies have shown the use of complex training, using strength and plyometric training together as a means of gaining power to increase performance (Ebben, W.P. 2002). For the athlete that needs to kick, punch, and perform takedowns with more speed and force, increases in power can have positive increases on performance (Jamieson, J. 2009).

The use of strength training as a training program attempts to increase optimal gains in strength, power, motor performance, and/or muscle hypertrophy (Fleck, S.J. 1999). Increasing maximal strength through strength training can increase the force a muscle or groups of muscle can apply. Because force is a component of power, (P=F x V), it inadvertently increases power, which is evident in numerous studies (Stone, M.H., Moir, G., Glaister, M., Sanders, R. 2002; Wisloff, U., Castagna, C., Helgerud, J., Jones, R., Hoff, J. 2004; Peterson, M.D., Alvar, B.A., Rhea, M.R. 2006). Several studies indicate that an increase in maximal strength results in an increase in power. To further illustrate the premise, Hakkinen (1994) posed three possible ways an increase in maximum strength can affect peak power. First, a given load would represent a smaller percentage of maximum, thus making the load easier to accelerate. Secondly, it is possible for an athlete with a higher maximum strength level would have a greater percentage of type II muscle fibers which strongly contribute to high power outputs. Finally, as a result of an increased maximum strength, several power improving alterations occur including hypertrophy

of type II fibers, increases in type I and II cross sectional area and increases in neuromuscular activation through each motor unit.

Aagaard, P., Simonsen, E.B., Andersen, J.L., Magnusson, P., Dyhre-Poulsen, P. (2002) examined the increased rate of force production and neural drive of human skeletal muscle following a resistance training program. Fifteen male subjects performed progressive heavy-resistance strength training for 14 weeks for a total of 38 sessions. The subjects performed lower body exercises between four and five sets of each exercise ranging from 3 to 10 repetitions. Maximum lower body strength increased from 291 ± 9.8 N to 339 ± 10.2 N via the strength training regimen. In this study rate of force development was described as explosive muscle strength and has important functional significance in fast and forceful muscle contraction like those used in sprinting, karate and boxing. After training, the rate of force development increased in each participant by calculating the momentum at four different times during a single contraction. The times were 30, 50, 100, and 200 ms relative to the onset of contraction and increased from 1601 ± 117 to 2020 ± 119, 1802 ± 121 to 2201 ± 106, 1543 ± 83 to 1806 ± 69 and 1141 ± 45 to 1363 ± 44 N·m·s, respectively.

Another study used findings from other publications to determine the correct way to increase power in the upper and lower body (Baker, D.G., Newton, R.U. 2005). The study listed six different ways to increase maximum power that include: including full acceleration exercises as power exercises, alter the kinetics of some strength exercises to more favorably affect rapid-force or power output, use complex exercises, periodize the power and resistance exercises, use low repetitions when maximizing power output, use clusters, rest-pause, or breakdown techniques for some strength or power exercises, and use an ascending order of resistances when maximizing power output. The authors indicated that each technique would significantly

increase power (Baker, D.G., Newton, R.U. 2005). They also reported the importance of increasing upper body power for the purpose of enhancing an athlete's ability to push away or strike an opponent and recommend that it is advisable to maintain high levels of maximal strength if an athlete wishes to attain a high maximal power (Baker, D.G., Newton, R.U. 2005).

In another study, Baker, D., Wilson, G., Carlyon, R. (1994) provide more evidence that increasing maximal strength increases power. Twenty two male subjects were tested for maximum strength (1RM) in the squat and bench press, vertical jump, and also examined neural activation levels. Following the pretesting, the subjects were taken through a 12 week strength and conditioning intervention. The subjects were placed in one of three separate periodized training groups: linear, undulating, or non-periodized control model. Post test results showed a significant increase in strength for the bench press in each group ranging from 26.1 to 28.4%. A change in maximum strength in the bench press was also significant ranging from 12.5 to 16.4% in each of the three groups; however, the neural muscle activation remained relatively unchanged. In the vertical jump, a common assessment tool of lower body power, a proposed change of an 8.3% increase was observed during post tests for the entire group. This type of study lends evidence to the theory that an increase in strength can increase power after a resistance training program.

Izquierdo, M., Hakkinen, K., Ibanez, J., Garrues, M., Anton, A., Zuniga, A., … Gorostiaga, E.M. (2000) also indicated an increase in muscle power and strength in middle-aged (46 ± 2 yr.) and older men (64 ± 2 yr.) through resistance training designed to increase strength. In the study, 11 middle-aged and 11 older men were subjects of a 16 week strength training regimen that significantly increased strength and power in both groups. Maximal strength tests were determined by the one repetition maximum (1RM) test for the half squat and the bench

press while power was tested using by moving the bar as fast as possible using different percentages of the 1 RM in the bench press and half squat. The velocity and power were recorded during each lift through the use of linking a shuttle to the end part of a bar locked to an infrared sensor. The 16 weeks of strength training resulted in a significant increase in strength gains in the upper and lower body as well as significant gains in power. In the middle aged subject group, the 1RM in the half squat increased by 46 ± 6%, and by the older age group, 41 ± 16%. The 1RM bench press increased by 36 ± 13% in middle aged men and by 36 ± 11% in older men. The power increased at a relative load of 60% of 1RM in middle aged and older men, 29 ± 18 and 36 ± 22%, respectively, supporting the premise that an increase in strength can also increase power.

Further, Stone, M.H., O'Bryant, H.S., McCoy, L., Coglianese, R., Lehmkuhl, M., Schilling, B. (2003) indicated a high relationship between the 1RM squat and peak power production in the squat jump. Twenty two male subjects participated in the study that recorded a 1RM for the squat. The 5 strongest and the 5 weakest participants were compared and the 5 strongest participants were able to generate more power in the static squat jump and the countermovement squat jump. The strongest group was also able to generate their highest power outputs at the 40% of 1RM and the weakest group decreased in power as the load increased.

Power can also be increased through an increase in speed in the movement being performed. This increase in speed comes from the reactive neuromuscular system of the athlete (Ludin, P., Berg, W. 1991). Motor control in the athlete is directed by the central nervous system, using sensory feedback from the proprioceptors which contribute to an athlete's awareness of the body and its movements. The proprioceptors are the muscle receptors that

include the Golgi tendon organ and muscle spindle and control key components in gaining power from the training process through adaptations in speed (Ludin, P., Berg, W. 1991).

Plyometrics are used to improve power output and increase explosion by training the muscles to do more work in a short amount of time (Luebbers et al. 2003). Plyometrics are used to train athletes for an increase in power through optimizing the stretch shortening cycle. This cycle occurs when the active muscle switches from rapid deceleration to a rapid acceleration. The faster the muscle is stretched during the deceleration the more explosive the movement will be. The study used thirty-eight physically active men that were randomly assigned to two groups. One group trained in a 7-week training program and the other trained in a 4-week training program. The subjects performed the plyometric jump routines 3 times a week for each group. The plyometric exercises performed each day included double leg vertical jumps, tuck jumps, double leg broad jumps, single and double leg bounding, and depth jumps from a height of 40 cm. They were post tested at the end of each cycle and tested again after 4 weeks of recovery. The results show that through the plyometric training each group gained significant vertical jump height and gained significant amount of power. In terms of vertical jump height, the 4-week program was superior to the 7-week program. The 7-week program was superior in all other areas that included vertical jump power and Margaria power, which is a staircase power test that record the time takes between a subject's steps and entered into the formula ($P=(W \cdot D)/t$) to give power output for a subject.

In another study that demonstrates the effects of plyometric training, Potteiger, J.A., Lockwood, R.H., Haub, M.D., Dolezal, B.A., Almuzaina, K.S., Schroeder, J.M., Zebas, C.J. (1999) identified the effects of muscle power and fiber type characteristics after 8 weeks of plyometric training. Nineteen men participated in a study where they were randomly selected for

a plyometric group or a plyometric group and aerobic group. Each exercise was performed 3 times a week for an 8-week duration. Both groups were recorded as having a significant increase in the vertical jump height and peak power. The plyometric group increased vertical jump height by 2 cm and increased peak power by ~250W. The plyometric and aerobic conditioning group also showed increases in their vertical jump (3.1cm) and peak power (~225W).

Another study (Gehri, D.J., Ricard, M.D., Kleiner, D.M., Kirkendall, D.T. 1998) compared different techniques of plyometric training for improving vertical jump ability and energy production. They used 28 subjects, 14 male and 14 female, to participate in 12 weeks of plyometric training. The subjects were placed in 1 of 3 groups; control, depth jump training, or countermovement jump training. Each training group resulted in a significantly higher vertical jump; however, the depth jump training group was the only one to significantly increase in all 3 jumps. Together, these studies on plyometrics demonstrate the ability to increase power through increasing the speed of a proprioceptive reaction.

Complex Training

Most methods of increasing power either use plyometric training or strength training to increase power. A popular modern way of gaining peak power is to combine the two methods of plyometric and strength training. This method is referred to as complex training and is defined as alternating biomechanically similar high load weight training with plyometrics for a maximum gain in strength and power. There is statistical evidence that complex training is superior to that of plyometric and strength training alone (Ebben, W.P. 2002).

In one study, Adams, K., O'Shae, J.P., O'Shae, K.L., Climstein, M. (1992) compared three different methods of training to increase the vertical jump. The subjects were randomly selected into four groups: squat, plyometric, squat-plyometric, and control. The study concluded

that the squat-plyometric group was significantly better, 10.67 cm, than any other group in the study, squat 3.3 cm and plyometric 3.8 cm. Although the squat and plyometric groups were not significant in increasing the power as detected by the vertical jump, they did result in higher vertical jumps in the post testing. The only group that did not increase the lower body power production was the control group.

Another study examined the effects of complex training on physical fitness, body composition, and knee extension velocity during kicking in football (Perez-Gomez, J., Olmedillas, H., Delgado-Guerra, S., Ara Royo, I., Vicente-Rodriguez, G., Arteaga Ortiz, R., … Calbet, J.A.L. 2008). The rationale was that weight training increases the maximal dynamic force and plyometrics increase the speed and force on muscle contraction. The study used 42 students that were randomly assigned to a strength training group or a control group. The strength training group followed a periodized 6 week training program consisting of 3 sessions per week. The plyometrics were performed first during the training session and the strength exercises were performed last. By combining these two, the complex training method resulted in improvements in the countermovement vertical jump velocity (+2.4 m/s ±.05 m/s), height jumped (+.02 m ±.01 m), maximal instantaneous vertical velocity (+.09 m/s ±.05 m/s) and maximal instantaneous power (+250 W ±114.6 W). It also improved kicking performance and maximal dynamic force. This study provides additional evidence that complex training may be superior to any other training method at enhancing power and strength in athletes of any sport.

There has always been controversy concerning the transfer of strength training to various athletic performance variables. One study (Harris, G.R., Stone, M.H., O'Bryant, H.S., Proulx, C.M., Johnson, R.L. 2000) identifies the transfer of strength training in functional variables showing the short-term performance effects of high power, high force, and combined weight

training methods. The high force group used 80%-85% of 1RM during their training periods. The high power group used approximately 30% of their 1RM during each training session and the combined group used both methods. The results indicated the high force group significantly improved their 1RM squat, ¼ squat, 1RM mid-thigh pull, and Margaria-Kalamen power test. The high power group significantly increased in the vertical hump, ¼ squat, 1RM mid-thigh pull, Margaria-Kalamen power test, and the standing long jump. Finally the combined group significantly increased in the 1RM squat, ¼ squat, 1RM mid-thigh pull, vertical jump, vertical jump power, and the 10 yard shuttle run. These results indicate that when needing improvement in athletic performance in a wide variety of variables, complex training produces superior results than training for maximal strength or maximal speed.

In conclusion, there have been many studies that determine the proper way to increase power and strength and the effects these increases have on the performance of the participants. An increase in power can be determined through an increase in strength, speed, or both. An increase in strength usually comes from a periodized strength protocol and has been shown to increase power as an independent factor. Studies in complex training have indicated that it is superior to plyometric or strength training alone and that plyometric and strength training should be performed together as part of the same training session.

Relationship between Power and Vertical Jump, Sprint Times and Agility and Their use as a Performance Index

Success in many sports seems to rely heavily upon the participant possessing an adequate degree of various physical qualities such as strength, power, speed, and agility as well as individual skills to participate in the sport of choice. Different strength and conditioning specialists and coaches attempt to predict the functional performance of an athlete through

different physical characteristics that include vertical jump, speed, and agility tests (Davis, D.S., Barnette, B.J., Kiger, J.T., Mirasola, J.J., Young, S.M. 2004; Gabbett, T.J. 2002 and 2010; Hoare, D.G., Warr C.R. 2010). The characteristics are different depending on the demands of the sport. For instance, the physical characteristics between soccer forward and an American football offensive lineman will be different because their anthropometric and physiological demands differ in response to their sport; therefore, the outcome of certain performance tests, such as, the vertical jump, pro agility shuttle and 10 yard sprint, should be different considering the sport and the athlete.

The correlation between vertical jump and power has been shown to have a strong relationship (Carlock, J.M., Smith, S.L., Hartman, M.J., Morris, R.T., Ciroslan, D.A., Pierce, K.C., … Stone, M.H. 2004; Hori, N., Newton, R.U., Andrews, W.A., Kawamori, N., McGuigan, M.R., Nosaka, K. 2008; Wisloff et al. 2004). Carlock et al. (2004) determined that both types of vertical jumps, countermovement vertical jump and static jump, were correlated to weightlifting ability. Both men and women (n=64) Olympic weightlifters from the Olympic Training Center in Colorado Springs, CO were used as subjects for this study. Through simple calculations the jump height and peak power were taken in both jumps. A questionnaire was filled out by each participant determining their current weightlifting status and was checked again by their weightlifting coach for inaccuracies. The jump height and power of each jump showed a high correlation with weightlifting movements: squat, snatch, and clean and jerk. The peak power of the countermovement vertical jump (CMJ) and static jump (SJ) correlated with the snatch at r=.93 and r=.76 for men and women, respectively. The CMJ and clean and jerk had high correlation values at r=.90 and r=.76 for men and women, respectively. Not only did this study indicate a high correlation between peak power (CMJ and SJ) and explosive power movements

(snatch and clean and jerk), it also demonstrates the high correlation between maximal strength (front squat 1RM) and peak power. Peak power of the CMJ and SJ and the squat had a high positive correlation of r=.91 for men and r=.82 for women. This study provides evidence that the vertical jump tests can be a used as a valid indicator of power and strength.

In another study, Wisloff and colleagues (2004) determined the correlation between maximal squat strength with sprint ability and vertical jump height. The study used (n=17) elite male soccer players that were assessed in vertical jump height, 30 m sprint test, 10 m shuttle run and maximal strength, among other tests. The results of the study showed a high correlation between maximal strength and vertical jump (r=.78), sprint ability (r=.71) and 10 m shuttle run (r=.68). The vertical jump and 30 m sprint time had a relatively strong correlation (r=.60) as well. This is another study that gives evidence that high positive correlations do exist between functional tests (vertical jump, 30 m sprint time, and 10 m shuttle) and maximal strength and power.

Hori et.al (2008) investigated the correlation between the hang clean, a common explosive weightlifting exercise, with sprinting, jumping, and agility. Twenty-nine semiprofessional Australian Rules football players participated in 7 measurements that consisted of the 1RM hang clean, 1RM front squat, CMJ with a 40 kg barbell, CMJ without a load, CMJ height, 20 meter sprint ability and the 5-5 drill to test agility. After the initial test of the hang clean, the twenty-nine participants were divided into two groups. The first group represented the top 50% of the hang clean maximum and the second group represented the bottom 50% of the hang clean maximum. The results of the study determined the top 50% of the 1RM hang clean exhibited significantly greater values than the bottom 50% except for CMJ height, CMJ for peak power, and the 5-5 agility drill. However, there were significant correlations found between the

hang clean 1RM and the measures of maximum strength, power, CMJ height, 20 m sprint, and the 5-5 agility drill. All the statistics shown in this study were relative to the participants' body mass. This study further represents a strong positive relationship between strength, power, speed and agility.

Another study that demonstrates a similar strong positive relationship between maximal force and power production with vertical jump, sprint ability and agility was investigated by Peterson et.al (2006). The study involved 19 men and 36 women (n=54) that were tested in lower body muscular strength in the 1RM back squat, CMJ height and peak power, standing broad jump, agility and sprint time. Significant linear relationships were found between lower body strength and peak power (r=.91), lower body strength and vertical jump (r=.85), lower body strength and broad jump (r=.76), lower body strength and agility test (r=.78), and lower body strength and sprint tests (r=.85). A positive correlation was also shown between all field tests as well. This study demonstrates the possibility of being able to predict performance of an athlete when one or more values are already known about the athlete.

Because performances in certain functional tests have shown to be positively correlated with playing ability and level of play in college football players, much emphasis is placed on these tests by strength and conditioning coaches. One study suggests the physical characteristics that predict functional performance in Division I football players; because, football players are often ranked by their performance in these tests (Davis et al. 2004). Physical and functional assessments of 46 NCAA Division I college football players were assessed to identify the predictive ability and functional characteristics of these athletes. The data included player body weight, hamstring length, 40 yard sprint time, 20 yard shuttle run, vertical jump height, and 1RM values for the hang clean and bench press. The functional characteristics were

the 40 yard sprint time, 20 yard shuttle run time and the vertical jump. They were compared to the height, weight, percent body fat, hamstring length and the 1RM for the hang clean and bench press. The 40 yard sprint had a significant negative relationship to body weight, bench press and hang clean. We then make suggestions based on the interpretation of the analysis that the hang clean and bench press were negatively correlated, which indicates the stronger a player is in the bench press and hang clean, the slower the player will run the 40 yard sprint. The 40 yard sprint time had a positive correlation with the body weight which suggests as the body weight increases the 40 yard sprint time increases as well. This model explained 85% of the variability of the 40 yard sprint time in college football players. Body weight was positively correlated with the 20 yard shuttle run and the sit and reach, and negatively correlated with the hang clean and bench press. This would suggest that as body weigh increases the 20 yard shuttle time would decrease and as the sit and reach test, hang clean and bench press decrease, the shuttle time decreases. This study is evidence that performance in football players is controlled by the athlete's body weight. None of the variables were significantly correlated to the vertical jump in this study. Investigations like this demonstrate the possibility to predict performance through a battery of tests in football players.

Some scientists have studied the physiological characteristics that determine an elite player in various sports. Gabbett (2002) investigated the physiological characteristics of junior and senior rugby league players competing at the sub-elite level in order to establish performance standards for these athletes. A total of 159 rugby players were selected from the same league to participate in the study. Their body mass, vertical jump, speed (10 m, 20 m, and 40 m), agility, and established Vo_2MAX were assessed. The investigation determined that the longer an athlete had played, the better the numbers of the test. The data proves to be a guideline for coaches and

sport scientist to evaluate talent by age and league group. For example, if a player being evaluated has speed and agility numbers above those found in this study and power and strength numbers below those found in this study for their league and age level, that athlete may not be able to compete at the next level. The opposite could also be true in an athlete whose numbers are much better than those found within the age group and league group. That athlete may be able to advance to the next level earlier than some of his peers.

In a study trying to identify talent in women's soccer players, Hoare and Warr (2010) performance tested 59 female athletes, that had never played soccer, in the vertical jump, 5-m sprint, 10-m sprint, 20-m sprint, 505 agility, multi-stage fitness test score, predicted maximal aerobic power, height, body mass, overall performance index, and weighted average index. At the conclusion of the final tests, the number of participants was decreased to 17 athletes. The decrease in athletes was due to the selection of top athletes. Of the 17 players left, two were awarded elite soccer scholarships, four players were retained by a talent search program, six athletes were selected to play for the premier league clubs, while two played reserve grade. Three of the players made a state team selection and one of those was named tournament most valuable player. This research demonstrates the possibility of selecting athletes for certain sports through evaluation of physiological, anthropometric, and skill attributes.

Using performance tests that involve agility, speed and power as a way of predicting athletic ability in any type of sport has long been studied. Elite athletes in their respective sport usually have more speed, agility, power, and/or strength than those who never make it to the elite level. An athlete's agility, speed and power should be a included as a predictor of how well an athlete can compete at a certain level of a desired sport.

Tendo Power and Speed Analyzer and NSCA Performance Index

The Tendo Power and Speed Analyzer (Tendo PSA310) is made by Tendo Sports Machines (Tendo Unit, Slovak Republic) and measures power and velocity through speed of movement and force. The Tendo Unit consists of two functional components; the velocity sensor unit and a microcomputer. The velocity sensor is mounted on the metal pole of a Vertec to ensure proper height adjustment for measurement of the techniques. The velocity sensor unit is connected to a belt by means of a Kevlar cable with a Velcro strap and is connected to the microcomputer via a VSU cable. The Velcro strap connects securely around the belt of the main point of movement. The outcome measures of the Tendo Unit are peak and average power, measured in watts (W), and peak and average velocity, measured in meters per second (m/s). Weight, in kilograms, and filter, proposed length of movement set at 35cm, are entered into the microcomputer before testing begins. The data is recorded and stored in the computer for up to 50 repetitions.

In an attempt to find other studies that used the Tendo Power and Speed Analyzer (Tendo Unit) the investigators could only find a few studies that were used to test the power and velocity of a bar during some type of weight lifting exercise. These investigations used the Tendo Weightlifting Analyzer, which is specifically used to test the power and velocity of some type of weight lifting exercise (Rucci et al. 2010). There was no investigation that used the Tendo Power and Speed Analyzer the way the present investigation used this device.

The NSCA performance index was developed by the NSCA to quantify power, agility and speed in athletes. It is a scoring system based on the results of the vertical jump, pro-agility shuttle, and 10 yard sprint combined with age and gender and is designed to score each participant in a percentile ranking based on each performance. The final score is the average of

the three percentiles and has been developed for specific age groups. There have been investigations that develop a performance index; however, at the time of the present investigation, no scientific investigation could be found that used the NSCA performance index as a way to determine athletic performance in a specific sport and there had been no reported index developed for determining functional ability of mixed martial artists. This index was chosen after careful consideration and investigation into the individual components of MMA techniques. The use of power is very evident in MMA techniques and a correlation between the assessments that compose the NSCA performance index and power measures in other sports have been studied extensively.

Conclusion

Through an extensive review of literature, the lack of information on MMA as a sport is very apparent. In terms of strength and conditioning, the evidence is almost nonexistent with the exception of a few strength and conditioning coaches and scientists who have made considerations of how to train a MMA athlete through existing scientific research that has identified possible ways to increase strength and power in other sports. This research had identified ways to increase power through increases in strength and/or speed and the increases in performance that mirror these increases. Strength has also been identified as a way to increase performance through the ability to apply more force to the functional task being performed, such as being able to apply more force to the ground during a vertical jump or throwing a punch or knee.

An extensive review of literature also shows how other sports use a performance index to determine functional abilities in sports such as the battery of tests potential professional football players endure at the NFL combine. There is a lack of research in determining predictive

functional measures through a battery of tests in mixed martial arts. The indication of how the vertical jump, pro-agility shuttle, and the 10 yard sprint ability correlates to peak power ability in mixed martial artists has yet to be determined. These tests are used, however, as an indication of athletic ability in other sports such as soccer, rugby, and football.

References

Aagaard, P., Simonsen, E.B., Andersen, J.L., Magnusson, P., Dyhre-Poulsen, P. (2002). Increase rate of force development and neural drive of human skeletal muscle following resistance training. *Journal of Applied Physiology*, 93, 1318-1326. doi: 10.1152/japplphysiol.00283.2002

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

Amtmann, J.A. (2004). Self-Reported Training Methods of Mixed Martial Artists at a Regional Reality Fighting Event. *Journal of Strength and Conditioning Research*, 18(1), 194-196.

Amtmann, J. (2010). High Intensity Training and the Mixed Martial Artist. In J.E. Warnick (Ed.), *Advancements in the Scientific Study of Combative Sports.* (pp.13-39). © 2010 Nova Science Publishers, Inc.

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

Baker, D.G., Newton, R.U. (2005). Methods to increase the effectiveness of maximal power training for the upper body. *National Strength and Conditioning Association*, 27, 24-32.

Buse, G.J., Santana, J.C. (2008). Conditioning strategies for competitive kickboxing. *Strength and Conditioning Journal*, 30, 42-48.

Carlock, J.M., Smith, S.L., Hartman, M.J., Morris, R.T., Ciroslan, D.A., Pierce, K.C., Newton, R.U., Harman, E.A., Sands, W.A., Stone, M.H. (2004). The relationship between vertical jump

power estimates and weightlifting ability: A field test approach. *Journal of Strength and Conditioning Research*, 18, 534-539.

Davis, D.S., Barnette, B.J., Kiger, J.T., Mirasola, J.J., Young, S.M. (2004). Physical characteristics that predict functional performance in Division I college football players. *Journal of Strength and Conditioning Research*, 18, 115-120.

Ebben, W.P. (2002). Complex Training: A brief Review. *Journal of Sports Science and Medicine*, 1, 42-46.

Fleck, S.J. (1999). Periodized strength training: a critical review. *Journal of Strength and Conditioning Research*, 13, 82-89.

Gabbett, T.J. (2010). Influence of physiological characteristics on selection in a semi-professional first grade rugby league team: a case study. *Journal of Sports Sciences*, 20, 399-405.

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

Glassman, G. (2003). Metabolic conditioning. *Crossfit Journal Articles*, 10, 1-4.

Hakkinen, K. (1994). Neuromuscular adaptation during strength training, aging, detraining, and immobilization. *Critical Reviews in Physical and Rehabilitation Medicine*, 6, 161-198.

Harris, G.R., Stone, M.H., O'Bryant, H.S., Proulx, C.M., Johnson, R.L. (2000). Short-term performance of high power, high force, and combined weight-training methods. *Journal of Strength and Conditioning Research*, 14, 14-20.

Hori, N., Newton, R.U., Andrews, W.A., Kawamori, N., McGuigan, M.R., Nosaka, K. (2008). Does the performance of hang clean differentiate performance of jumping, sprinting, and changing of direction? *Journal of Strength and Conditioning Research*, 22, 412-418.

Izquierdo, M., Hakkinen, K., Ibanez, J., Garrues, M., Anton, A., Zuniga, A., Larrion, J.L., Gorostiaga, E.M. (2000). Effects of strength training on muscle power and serum hormones in middle-aged and older men. *Journal of Applied Physiology*, 90, 1497-1507.

Jamieson, J. (2009). *Ultimate MMA Conditioning*. Performance Sports Inc.

Jandacka, D., Vaverka, F. (2008). A Regression Model to Determine Load for Maximum Power Output. *Sports Biomechanics*, 7(3), 361-371.

Komi, P.V. (Ed.). (2004). *Strength and Power in Sport*. Malden, MA: Blackwell Science, Inc.

La Bounty, P., Campbell, B.I., Galvan, E., Cooke, M., Antonio, J. (2011). Strength and conditioning considerations for mixed martial arts. *Strength and Conditioning Journal*, 33, 56-67.

Ludin, P., Berg, W. (1991). A review of plyometric training. *National Strength and Conditioning Association Journal*, 13, 22-30.

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

Perez-Gomez, J., Olmedillas, H., Delgado-Guerra, S., Ara Royo, I., Vicente-Rodriguez, G., Arteaga Ortiz, R., Chavarren, J., Calbet, J.A.L. (2008). Effects of weight lifting training combined with plyometric exercises on physical fitness, body composition, and knee extension velocity during kicking in football. *Applied Physiology, Nutrition, and Metabolism*, 33, 501-510.

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, 867-873.

Potteiger, J.A., Lockwood, R.H., Haub, M.D., Dolezal, B.A., Almuzaina, K.S., Schroeder, J.M., Zebas, C.J. (1999). Muscle Power and Fiber Characteristics Following 8 Weeks of Plyometric

Rucci, J.A., Tomporowski, P.D. (2010). Three types of kinematic feedback and the execution of the hang power clean. *Journal of Strength and Conditioning Research*, 24, 771-778.

Training. *Journal of Strength and Conditioning Research*, 13, 275-279.

Rooney, M. (2008). *Training for Warriors*. New York, NY: HarperCollins Publishers.

Rooney, M. (2010). *Ultimate Warrior Workouts*. New York, NY: HarperCollins Publishers.

Siff, M.C. (2000). *Supertraining*, 5th Ed. Denver, CO: Supertraining Institute.

Stone, M.H., Moir, G., Glaister, M., Sanders, R. (2002). How much strength is necessary? *Physical Therapy in Sport*, 3, 88-96.

Stone, M.H., O'Bryant, H.S., McCoy, L., Coglianese, R., Lehmkuhl, M., Schilling, B. (2003). Power of Maximum strength relationships during performance of dynamic and static weighted jumps. *Journal of Strength and Conditioning Research*, 17, 140-147.

Turner, A.N. (2009). Strength and conditioning for Muay Thai athletes. *Strength and Conditioning Journal*, 31, 78-92.

Wisloff, U., Castagna, C., Helgerud, J., Jones, R., Hoff, J. (2004). Strong correlation of maximal squat strength with sprint performance and vertical jump height in elite soccer players. *British Journal of Sports Medicine*, 38, 285-288.

CHAPTER 3

[1]Effects of an Eight Week Training Intervention on Peak Power in Mixed Martial Arts Techniques

Clay H. Walker, Michael Horvat, Bryan A. McCullick, Jonathan Templin, Michael Ferrara, Adam Singer

Movement Studies Laboratory, Department of Kinesiology, University of Georgia, Athens, Georgia

[1] To be submitted to The Journal of Strength and Conditioning

ABSTRACT

The purpose of this investigation was to determine the relationship between an 8-week strength and conditioning program and the peak power in 3 commonly used mixed martial arts techniques. Nineteen male mixed martial artists were assessed on maximal strength measures (1RM deadlift and 1RM bench press) and power measurements (vertical jump and 60% 1RM bench press) prior to the intervention, week 4 and week 8 of a strength and conditioning intervention. Peak power output was also assessed in the cross, rear knee, and double leg takedown. The results indicate an increase in the assessments of power and strength with the exception of the upper body power assessment. These measures were significant in increasing peak power in MMA techniques. The peak power of the cross was increased due to an increase in strength in the deadlift ($p=0.05$) and the interaction of the deadlift and bench press ($p=0.06$). The peak power of the rear knee was increased due to an increase in the strength in the deadlift ($p=0.002$) and the interaction of the deadlift and bench press ($p=0.06$). The rear knee is significantly influenced by an increase in vertical jump height ($p=0.04$). The double leg takedown was significantly influenced by the interaction between 60% 1RM bench press and vertical jump ($p=0.09$). The results of the present investigation indicate that the significant power or strength that helps explain the increase in peak power can be explained by the movement of each technique.

Key Words: mixed martial arts, MMA, strength, power

INTRODUCTION

Overview of the Sport of MMA

The origins of mixed martial arts (MMA) have been traced to the ancient Greek sport of pankration (22). The literal translation of pankration is "all powers" and was a mixture of Hellenic boxing and wrestling involving close quarters combat between 2 participants. The influence of pankration into the Greek ethos of strengthening the mind, body and spirit lead to its inclusion into the Olympic Games in 649 B.C. Modern MMA is a summation of various fighting styles including boxing, wrestling, Muay Thai boxing, kickboxing, judo and Brazilian Jui Jitsu and has hit main stream popularity over the past ten years (22). With MMA athletes encompassing a large variety of skills from diverse styles of martial arts, proper strength and conditioning training is required to help develop the overall fitness of the athlete preparing for a competition (4). According to Amtmann (5) no other sport requires the volume of training required to excel in mixed martial arts.

Importance of Strength and Conditioning in MMA

The importance of strength and conditioning programs have been linked to improvement in sports performance and developed to meet the variable requirements of many sports (6,30). For example, in MMA, the primary objective is the submission of one's opponent accomplished through various takedowns and locks or even by knockout blows using the hands, knees, and feet. With the improvement evident in other sports, it is not speculative that an effective strength and conditioning program can help MMA athletes develop the potential to generate more power and strength in striking and grappling.

In the sport of MMA, power and strength are the two underlying principles in the development of striking and grappling techniques. The more powerful a participant's blow, the

more effective he can be in competition. Stronger participants are more durable in sustaining posture under the various pressures of blows and grappling techniques that are prevalent in the sport.

Power, as defined in sport, is the product of force and velocity; or, it can also be defined as the rate of performing work (23). Peak power is the highest instantaneous value of power achieved during a movement and is the most important variable associated with success in athletic movement (12). Since power is a result of force and velocity, both of these principles become a factor when determining peak power and are dependent upon one another. The ability of the neuromuscular system to produce maximal power output appears to be crucial in many sports that require optimal combinations of muscle strength and speed to maximize athletic performance (6). For the MMA athlete, the combination of these two factors is important in perfecting MMA techniques.

Power can be increased by increasing strength and/or increasing the speed of movement (21,23,24,30). Numerous studies have reported increases in maximal strength and resulting increases in power (1,7,9,13,32). The use of strength training as a training program attempts to increase optimal gains in strength, power, motor performance, and/or muscle hypertrophy (17). Increasing maximal strength through strength training can increase the force a muscle or groups of muscle can apply. Because force is a component of power, (P=F x V), it inadvertently increases power, which is evident in numerous studies (27,31,34).

Purpose

While it is generally understood that an increase in power may contribute to an increase in MMA performance, the influences of a specific strength training program on power production has not been studied in MMA. Therefore, the primary purpose of this study was to

investigate the development of strength and power production among MMA through an 8 week training program. In addition, the relationship of strength and power was studied on the primary strikes used in MMA. To the knowledge of the investigators, this is the first study to examine the effects of an increase in power and strength and its effects on techniques used in MMA. From the perspective of the MMA strength and conditioning coach, this will give the first insight to how an MMA athlete responds to a strength and conditioning program that is designed to increase strength and power.

METHODS

Experimental Approach to the Problem

There is a lack of scientific information on the proper procedures used to increase power in functional techniques used in MMA. Learning how to optimize strength and power gains and consequently relating these increases to performance in each athlete is vital to understanding the procedure by which these athletes should be trained. While strength and conditioning has been studied extensively in other domains, there is no clear picture of the effects of increases in upper and lower body power and strength and how they translate to functional performance. This study will provide a foundation for future research in strength and conditioning for MMA athletes to provide specific training regimens for these athletes after proper assessment.

The sport of mixed martial arts requires its participants to train at a very high volume and intensity. Previously published research and books written on the subject of strength and conditioning for MMA are based on the research performed on athletes in other sports (3,5,11,20,28,29,33). While these coaches have valid theory on how to train these athletes through research performed in other sports, and through participating in the sport itself, it is

important for scientists to start using the MMA athlete as the population for study to help develop the proper training techniques needed to increase performance in that sport.

Subjects

Twenty-five male (19-34 years) mixed martial artists were recruited from the intermediate and advanced MMA class at The HardCore Gym in Athens, GA; however, only 19 subjects would be able to complete the entire study due to injuries that occurred during skills practice sessions. The owner of The HardCore Gym and the instructor of the intermediate and advanced classes identified potential participants who demonstrated a master level of performance in the cross, rear knee, and double leg takedown. Additional inclusion criteria included having participated in MMA for at least two years and participating in the intermediate or advanced classes at The HardCore Gym for at least three months to ensure the athletes had a solid skill and knowledge base to perform the techniques correctly and consistently. The participants practiced their MMA skills a minimum of 3 times and a maximum of 5 times a week throughout the study. They also participated in the investigation 3 days a week for a total of 6-8 training sessions a week. The participants signed an informed consent form and the study was approved by The University of Georgia's Institutional Review Board.

Instrumentation

The Tendo Power and Speed Analyzer (Tendo PSA310) made by Tendo Sports Machines (Tendo Unit, Slovak Republic), consists of two functional components: the velocity sensor unit and a microcomputer. The velocity sensor is mounted on the metal pole of a Vertec to ensure proper height adjustment for measurement of the techniques. The velocity sensor unit is connected to a belt by means of a Kevlar® cable with a Velcro® strap and is connected to a microcomputer via a VSU cable. The Velcro® strap connects securely around the belt of the

main point of movement for each technique. The Tendo Unit reports peak and average power, measured in watts (W), and peak and average velocity, measured in meters per second (m/s). Mass, in kilograms, and filter, which is the proposed length of movement set at 35cm, is entered into the microcomputer before testing begins. A Pearson Correlation was also used to determine the test-retest reliability of this instrument. The correlation shows a high positive correlation for the cross (0.96), the rear knee (0.88), and the double leg takedown (0.90). The unit was calibrated at the factory to ensure its accuracy in detecting the speed and force used by these participants. In addition, University of Georgia Department of Engineering verified the instruments ability to measure muscle power generated by electrical power through the detection of movement.

Lower body strength was measured by the 1 repetition maximum (1RM) deadlift and lower body power was measured by the vertical jump. The deadlift is an exercise that works all the muscle groups of the lower body as well as the back (6). It was chosen because it would be easy to teach to a large number of athletes. The vertical jump was chosen because it has been shown to be a reliable test for lower body power (10,25). The upper body strength was measured by the 1RM bench press and the upper body power was measured by performing the bench press at 60% of the 1RM while the bar was connected to the Tendo Unit via a Velcro® strap (8,13).

Procedures

Three data points were used for testing analysis; pre-testing, 4 weeks and 8 weeks. Pre-testing assessments of power and strength occurred across three days to decrease fatigue, risk of injury, and allow optimal performance. On the first day of testing, the weight of each participant was collected, followed by a warm-up period of 5 minutes. Following the warm-up, each participant was introduced to the Tendo Unit and provided an opportunity to become familiar

with the unit by practicing no more than 10-30 repetitions of each technique, which consisted of the cross, rear knee and double leg takedown. During this time the researcher adjusted the Tendo for comfort and accuracy and answered any questions. The velocity sensor unit of the Tendo Unit was mounted on the metal pole of a Vertec and adjusted in height before each technique was performed. The pole was placed 12 inches behind the participant to ensure safety. For the cross, the participant wore a four ounce MMA glove and the strap of the Kevlar cable was placed around the distal end of the radius and ulna and the Tendo was adjusted so the cable exit was even with the shoulder. For the rear knee, the strap was placed around the femur in line with the superior aspect of the patella and for the double leg takedown; the strap was placed around the trunk in line with the iliac crest and posterior superior iliac spine or PSIS. Once the strap was placed in the proper position the sensor height was adjusted on the Vertec pole to be level with the strap placement. Each power and velocity measurement was recorded after each repetition of each technique. Once this testing was complete, the participant performed a one repetition maximum on the bench press. The outcome values included peak power for the 3 MMA techniques and an upper body maximum strength measure.

Forty-eight hours after the first day of testing, the participants were tested in the vertical jump, following a 5 minute warm-up period, to determine lower body power among other tests as part of a larger study. The participant stood under the vanes of a Vertec and reached as high as possible until the finger tips of the dominant hand touched the bottom vane. Three vertical jump trails were performed and the maximum height achieved was recorded.

Forty-eight hours after the second day of testing, the participants performed the 60% one repetition maximum bench press and the one repetition maximum deadlift. Following a warm-up period, a bench press was loaded with 60% of the one repetition maximum for each

participant and the Tendo Unit was connected to the end of the bar. The participant then performed three repetitions as explosively as possible. After a 10 minute rest period, day three testing ended with the one repetition maximum deadlift. The outcome measures for this day included the upper body power measure and the maximum lower body strength measure.

Strength and Conditioning Intervention

An eight week, three times per week, strength and conditioning intervention aimed at improving the power and strength of each individual occurred at The HardCore Gym. The strength and conditioning intervention designed for this study was grounded in theory and practical experience. The program was designed to add strength and power through proper periodization, volume, and intensity. It was based on the three principles of program design in strength and conditioning: 1) specificity, 2) overload, and 3) progression. The program was designed and implemented by a certified strength and conditioning coach with 12 years experience as a Division I college strength and conditioning coach.

The strength and conditioning intervention is illustrated in Table 3.1 (pg17), Table 3.2 (pg. 18) and Table 3.3 (pg. 19). Each training session lasted approximately 50 minutes, and the program was designed as a complex training program. Complex training is a training program that requires the athlete to train in both weight and plyometric training simultaneously and has been found to be superior to any other type of training for power and strength (2,15,16). In addition to the strength training program, the subjects were required to participate in at least 4 skills practices each week. Each skill session lasted approximately 1.25 to 1.5 hours and included practices for boxing, kickboxing, Brazilian Jui Jitsu, wrestling and MMA (all forms of martial arts are combined into the MMA practice).

Statistical Analysis

The purpose of this analysis was to determine if an increase in power and strength was significant in increasing peak power in 3 commonly used mixed martial arts techniques. The analysis was to also determine which strength and power measures were responsible for the increase in peak power in these techniques. The peak power of the cross (PPC), rear knee (PPK), and double leg takedown (PP2DL) were recorded at three different times. The power assessments were the countermovement vertical jump (VJ) for the lower body and the bench press for power (BPP) for the upper body. The strength assessments were the 1RM deadlift (DL) for the lower body and the 1RM bench press (BPS) for the upper body. A hierarchical linear model was used to control for dependency because of the repeated measures. For this analysis, SAS 9.2 (Cary, NC) was used to analyze the data and the alpha level was set at $\alpha=0.10$. The alpha level was set at $\alpha=0.10$ because of the large probability of making a type 2 error which identifies there is not a significant difference in the statistical data when a significant difference really exists.

RESULTS

Figures 3.1, 3.2, and 3.3 (pgs. 21, 22, and 23) illustrate the change in peak power through each testing period for the cross (PPC), rear knee (PPK) and double leg takedown (PP2DL), respectively. Table 3.4 (pg. 20) illustrates the increase in peak power for each of the 3 MMA techniques and Table 3.5 (pg. 20) illustrates the percent change in peak power for each MMA technique.

Table 3.6 (pg. 20) reports the mean of each assessment for each testing period. The bench press for power increased from pre-test to mid-test and decreased from mid-test to post-test. The vertical jump, bench press for strength, and deadlift increased from pre-test to mid-test

and mid-test to post-test. Table 3.7 (pg. 20) shows the mean percentage change across each testing trail for each assessment.

A hierarchical regression was also used to determine the strength and power assessment that was significant to the increase in peak power for each MMA technique. The p-value (p) and Beta (β) values were reported after each analysis. The p-value indicates the independent variables that were significant to the change in the dependent variable and the beta values indicate how much change would occur if there was one unit increase in the significant variable. For the cross, the grand mean was taken for each of the variables. The analysis indicates that the deadlift ($p=0.05$) and the interaction between bench press for strength and deadlift ($p=0.09$) were significant in the increase in peak power. The beta values suggest that for every one kilogram increase in the deadlift, there is a 16.3 W increase in the cross and for every 1 kilogram increase in the bench press for strength and every 1 kg increase in the deadlift, there is a 0.44 W increase in the cross. All other variables and variable interactions were insignificant.

For the rear knee, the analysis shows that the deadlift ($p=0.002$) and bench press for strength interaction with deadlift ($p=0.06$) were significant in increasing peak power. Only one of the power measures, vertical jump, was significant ($p=0.04$) for the rear knee. The beta values show that for every one kilogram increase in the deadlift there would be an increase of 21.3 W of power on the knee and for every unit increase in the interaction in the bench press for strength and deadlift there was a 0.33 W increase in rear knee. The analysis also reported that for every one inch increase in vertical jump there is a 160.1 W increase in the peak power of the rear knee.

Finally, a hierarchical linear regression was used to examine each power and strength measure as a correlation to the significant increase in double leg takedown. The grand mean was taken for each variable and the analysis determined that only the interaction of two power

movements, bench press for power and vertical jump (p=0.09) was significant to the increase in power. The beta value suggests that for every one inch increase in vertical jump and one watt of power increase in the bench press there is a 0.73 W increase in the double leg takedown.

In conclusion, the analysis determined that, throughout the 8 week strength training program, the peak power of each technique increased as did strength and power as assessed by the deadlift, bench press, and vertical jump. The upper body power assessed by the bench press for power increased from pre-test to mid-test and decreased from mid-test to post-test. The analysis showed that the only significant contributors to the increase in peak power of the cross were the deadlift and bench press for strength and the interaction of these two measures. It also determined that increase in the deadlift, the interaction of the deadlift and bench press for strength, and the vertical jump had a significant effect on the power of the rear knee. For the peak power of the double leg takedown, the interaction of the bench press for power and vertical jump had the only significant effect.

DISCUSSION

Strength and conditioning is an important component in athletic training. Coaches are always searching for the proper way to strength train their athletes to facilitate a greater performance in competition, and there is a vast amount of published research available to guide coaches in creating a bigger, faster, stronger, and more powerful athlete. For the sport of MMA, strategies being used to train these athletes have been taken from research in other sports. The MMA athlete is very unique and the demands of the sport require him/her to train differently than any other athlete (5).

In addition to the overall increases in power and strength, the peak power of each of the 3 MMA techniques also increased. Predictably, the variables that were significantly responsible for

the increase in power differed for each technique. The deadlift ($p=0.05$ for cross and $p=0.002$ for knee) and the tandem of deadlift and bench press for strength ($p=0.09$ for cross and $p=0.06$ for rear knee) were significantly responsible for the increases in peak power for these two techniques. The results of this study show that the only significant variables that increased the peak power in the cross and rear knee are the enhanced strength variables. An increase in strength resulting in an increase in power can be supported by research from Izquierdo et al. (19), Stone et al. (31), and Stone et al. (32).

An explanation for the increase in strength and the interactions of those measures being significant in explaining the increases in the cross and rear knee can come from examining the techniques. The cross is used as the power punch in MMA. The athlete takes a 3 inch step forward toward the opponent as he throws a jab; this opens the hips for a potentially powerful rotation of the hips as the cross is thrown. The athlete rotates on the ball of the rear foot by driving the hips forward causing the athlete to apply force into the ground (26). Therefore, an increase in muscle force would allow the athlete to apply more force to the ground as the hips are rotated, thereby causing the cross to be more powerful.

Likewise, the rear knee follows a similar procedure. The athlete takes a 3 inch step toward the opponent, when the technique is performed, force is applied to the ground by the rear foot before the leg comes forward to strike with the knee; therefore, an increase in peak power of the rear knee can be contributed to applying more force to the ground. Another significant variable for an increase in the rear knee was the vertical jump. The vertical jump showed a negative beta value ($\beta=-160.1$) which indicated that a decrease in lower body power would negatively effect peak power of the rear knee. The vertical jump has been used extensively as a measure of lower body power (12,27,34) and a decrease in vertical jump could mean a lower

amount of power output for the rear knee. When studying the dynamics of the rear knee (26) it is determined that much of the power is derived from the lower body to deliver the rear knee effectively. Therefore, if the power of the lower body is decreased, the peak power of an athletic movement that involved the lower body would also decrease.

The significant variables for the increase in peak power of the double leg takedown was the interaction between the bench press for power and vertical jump ($p=0.09$). There is research that provides evidence that an increase in power can transfer to an increase in functional measurement like the double leg takedown (14). Further, there was no detection of an increase in strength being a significant factor in this movement. Examining this MMA technique (26), and consulting with a professional MMA coach that has been involved in the sport as an athlete or a coach for the last 15 years about these results, it was determined that the double leg takedown is considered a speed movement because it is used to get the athlete into position to apply the force to take the opponent down. In other words, the purpose of the movement is to get the athlete in position as quick as possible to then apply force and take the opponent down. There are two types of double leg takedowns. Some MMA athletes perform this technique as a "high double" and some perform it by using a "penetration step". The difference is when using a penetration step the athlete will step between the legs of the opponent. When the leg is through the opponent, the athlete's knee touches the ground and he pushes through the opponent to get the opponent's momentum going backward. As the momentum of the opponent is going backward, the athlete steps through and pulls the legs toward him and scoops the legs of the opponent, therefore taking the opponent to the ground. In contrast, the "high double" is a type of technique that is used much like a tackle in football. Because of this inconsistency, it is difficult

to apply force in this technique and compromise the consistency of applying the speed in this movement.

Conclusion

The investigation sought to determine whether an 8 week strength and conditioning intervention designed to increase power and strength could increase peak power in 3 MMA techniques: cross, rear knee, and double leg takedown. It was found the athletes increased in power and strength and also increased peak power in each of the 3 MMA techniques. An investigation into this phenomenon led the investigators to explain each significant variable that increased peak power through an explanation in each technique. It should also be noted that this investigation only used n=19 subjects. An increase in subjects would have increased the effect size therefore possibly rendering different results. An increase in the amount of times the subjects were tested would have increased the power of the study and the statistical analysis could have possibly been different by showing more statistically significant results.

It should be noted that this is the first study to investigate the significance an increase in power and strength has on MMA performance. Through this investigation, we determined that only certain, not all, variables were significant to the increase in peak power of each technique. Because this is a novel study, data that would help explain this phenomenon are scarce.

Future studies in strength and conditioning in MMA should look at performance effects in MMA after a strength training program and a plyometric training program separately. This would give insight to how effective each of these training programs would be on certain techniques. Another investigation in MMA would be an overtraining study. The aspect of overtraining in MMA is very present in each gym because of the nature of the sport. An

investigation into effective and efficient training in MMA would be an asset to the athletes that participate in MMA and its coaches.

PRACTICAL APPLICATION

Increases in strength and power through a strength training program can increase peak power in MMA techniques. Higher increases in lower body strength and lower body power as compared with upper body strength and power illustrates that MMA athletes may not understand the importance of training the lower body. Because all aspects of assessments and peak power measurements increased, a decrease in upper body power may give insight on how easy it may be to overtrain an MMA athlete's upper body. When dealing with a highly trained MMA athlete that needs to increase peak power for a certain technique, this study details the particular muscle groups responsible for increasing peak power; therefore, these muscle groups can be targeted and peak power can be increased.

Table 3.1 Strength and Conditioning Schedule for Weeks 1 and 5

Week 1 and 5		
Day 1	Day 2	Day 3
Warm-up	Warm-up	Warm-up
Bench Press	Sled Sprints x 6	Deadlift
Warm-up x 10	Pro Agility Shuttle x 5	Warm-up x 5
70% x 5	10 Yard Sprint x 5	70% x 5
75% x 5		75% x 5
80% x 5		80% x 5
Pull-up		Box Jump
3 x 5		3 x 5
Dumbell Bench		Lunge Walk
3 x 8		3 x 5 (each leg)
Medicine Ball Toss		Hurdle Bounds
3 x 5		3 x 5
Single Arm Row		Glute Ham Raise
3 x 5 (each arm)		3 x 8
Medicine Ball Punch		Calf Raises
3 x 5		3 x 10

Note. Sled Sprints were performed using a non-weighted Root Hog Sled (Sorinex Strength Equipment, Irma, SC) and was pushed for 30 yards.

Table 3.2 Strength and Conditioning Schedule for Weeks 2 and 6

Week 2 and 6		
Day 1	Day 2	Day 3
Warm-up	Warm-up	Warm-up
Bench Press	Sled Sprints x 8	Deadlift
Warm-up x 10	Pro Agility Shuttle x 8	Warm-up x 5
75% x 3	10 Yard Sprint x 8	75% x 3
80% x 3		80% x 3
85% x 3		85% x 3
Pull-up		Box Jump
3 x 5		3 x 5
Dumbell Bench		Lunge Walk
3 x 6		3 x 5 (each leg)
Medicine Ball Toss		Hurdle Bounds
3 x 5		3 x 5
Single Arm Row		Glute Ham Raise
3 x 5 (each arm)		3 x 8
Medicine Ball Punch		Calf Raises
3 x 5		3 x 10

Note. Sled Sprints were performed using a non-weighted Root Hog Sled (Sorinex Strength Equipment, Irma, SC) and was pushed for 30 yards.

Table 3.3 Strength and Conditioning Schedule for Weeks 3 and 7

Week 3 and 7		
Day 1	Day 2	Day 3
Warm-up	Warm-up	Warm-up
Bench Press	Sled Sprints x 10	Deadlift
Warm-up x 10	Pro Agility Shuttle x 10	Warm-up x 5
80% x 3	10 Yard Sprint x 10	80% x 3
90% x 3		90% x 3
95% x 3		95% x 3
Pull-up		Box Jump
3 x 5		3 x 5
Dumbell Bench		Lunge Walk
3 x 5		3 x 5 (each leg)
Medicine Ball Toss		Hurdle Bounds
3 x 5		3 x 5
Single Arm Row		Glute Ham Raise
3 x 5 (each arm)		3 x 5 (20lb vest)
Medicine Ball Punch		Calf Raises
3 x 5		3 x 10

Note. Sled Sprints were performed using a non-weighted Root Hog Sled (Sorinex Strength Equipment, Irma, SC) and was pushed for 30 yards.

Table 3.4 Increase in Peak Power of Mixed Martial Arts Techniques

Technique	Pre-test	Mid-test	Post-test
Cross	5025.5 W	5185 W	5325 W
Rear Knee	2400 W	3001 W	5401 W
Double Leg	1852 W	1895 W	1988 W

Table 3.5 Percent Increase in Mixed Martial Arts Techniques from Pre-test through Post-test

Technique	Pre-test to Mid-test	Mid-test to Post-test	Overall
Cross	2.60%	3.80%	6.50%
Rear Knee	25%	79%	125%
Double Leg	2%	4%	7.50%

Table 3.6 Change in Assessments

Assessment	Pre-test	Mid-test	Post-test
Deadlift	137 kg	147 kg	167 kg
Vertical Jump	23.5 in	24.5 in	25.25 in
Bench Press Strength	96 kg	101 kg	104 kg
Bench Press Power	601.8 W	615 W	589 W

Table 3.7 Percent Change in Assessments

Assessment	Pre-test to Mid-test	Mid-test to Post-test	Overall
Deadlift	8%	12%	21%
Vertical Jump	4.25%	3%	7.40%
Bench Press Strength	5%	3%	8.30%
Bench Press Power	2.14%	-4.40%	-2.20%

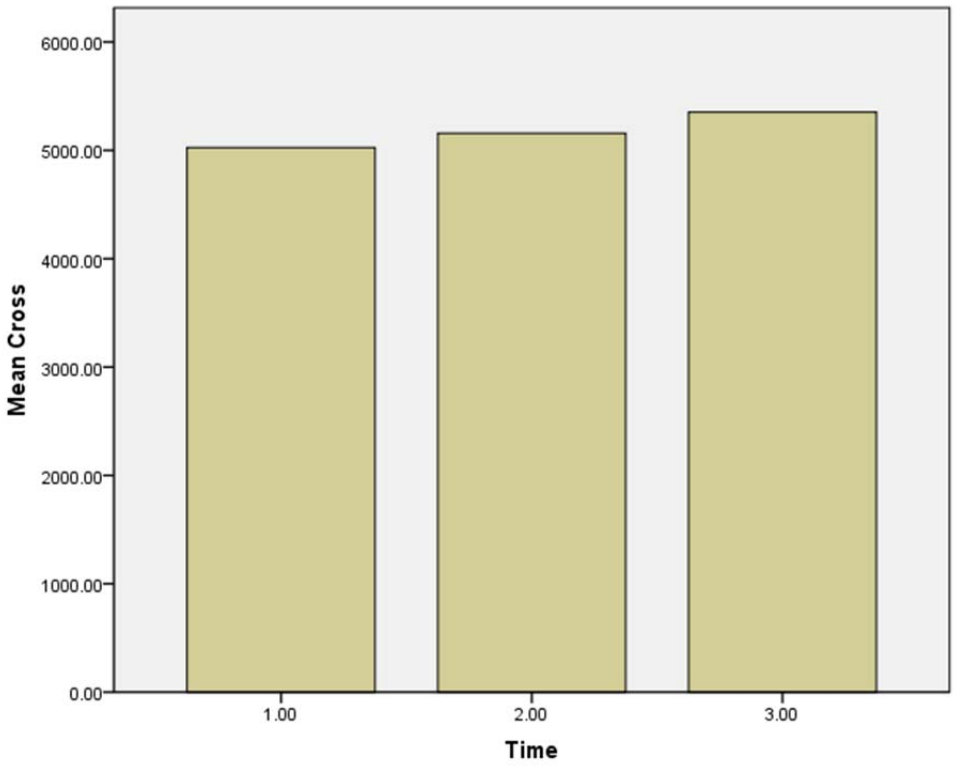

Figure 3.1 Increases in Peak Power of the Cross over Time

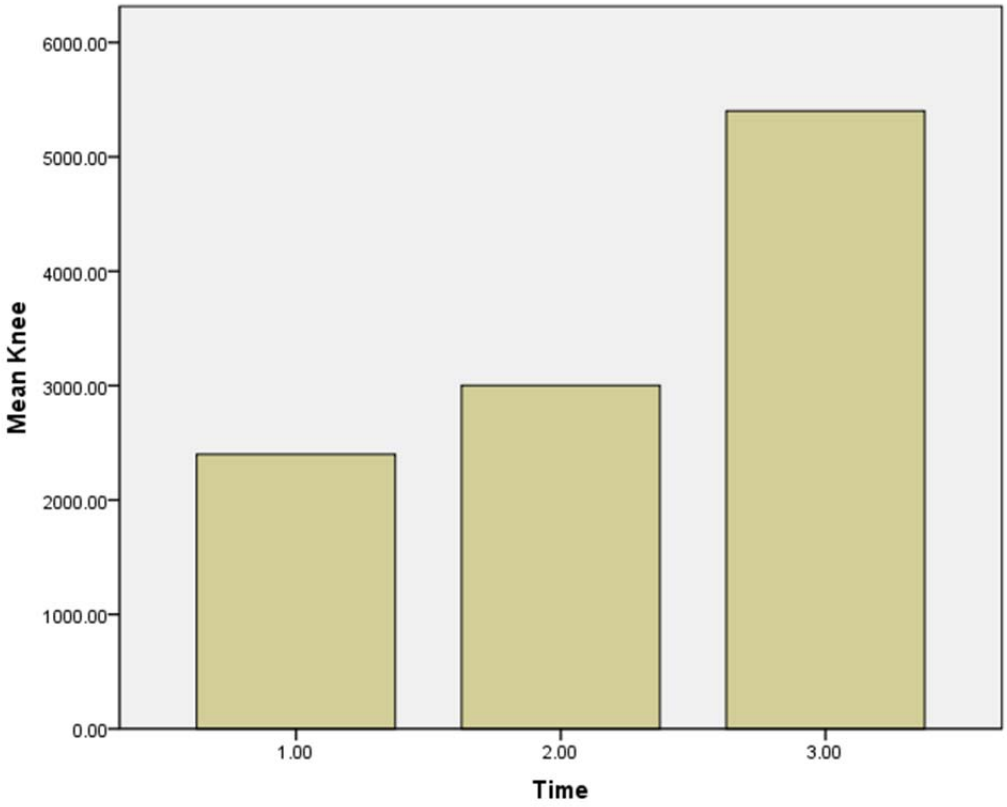

Figure 3.2 Increases in Peak Power of the Rear Knee over Time

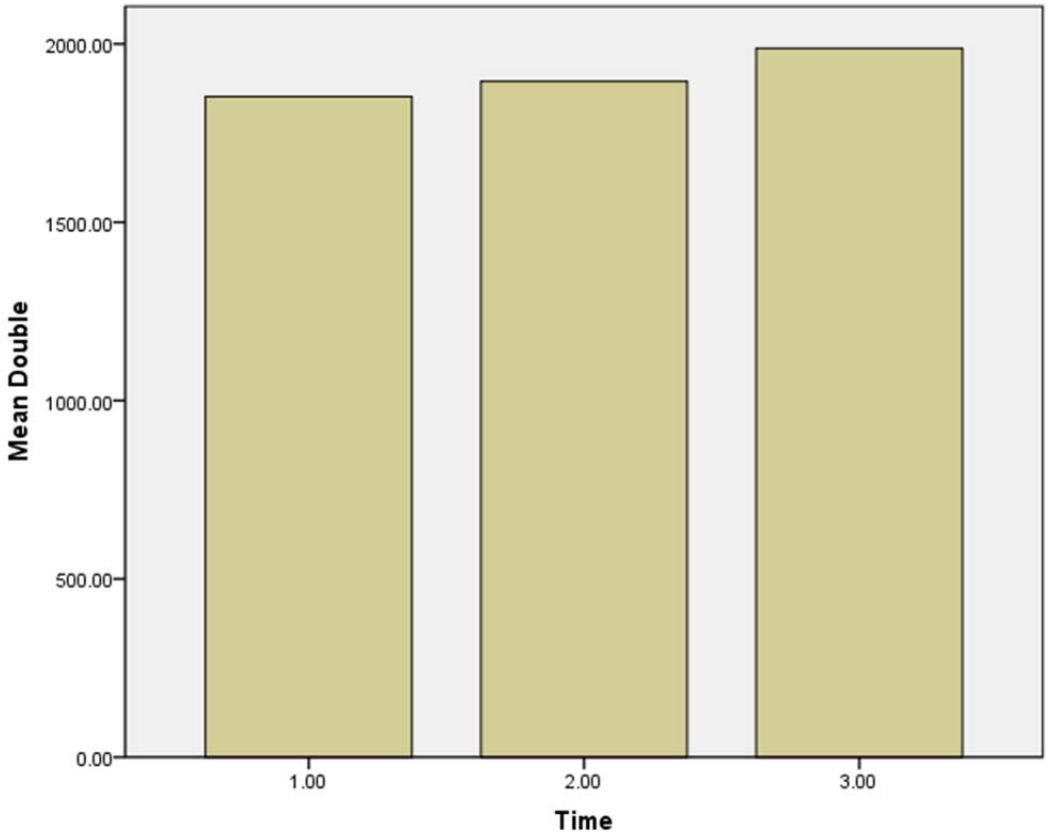

Figure 3.3 Increases in Peak Power of the Double Leg Takedown over Time

REFERENCES

1. Aagaard, P, Simonsen, EB, Andersen, JL, Magnusson, P, Dyhre-Poulsen, P. Increase rate of force development and neural drive of human skeletal muscle following resistance training. *Journal of Applied Physiology*, 93, 1318-1326, 2002.
2. Adams, K, O'Shae, JP, O'Shae, KL, Climstein, M. The effects of six weeks of squat, plyometric and squat-plyometric training on power production. *Journal of Applied Sport Science Research*, 6, 36-41, 1992.
3. Amtmann, JA. Self-reported training methods of mixed martial artists at a regional reality fighting event. *Journal of Strength and Conditioning Research*, 18(1), 194-196, 2004.
4. Amtmann, JA, Amtmann, KA, Spath, WK. Lactate and rate of perceived exertion responses of athletes training for and competing in a mixed martial arts event. *Journal of Strength and Conditioning Research*, 22, 645-647, 2008.
5. Amtmann, J. High intensity training and the mixed martial artist. In J.E. Warnick (Ed.), *Advancements in the Scientific Study of Combative Sports.* (pp.13-39). © 2010 Nova Science Publishers, Inc.
6. Baechle, TR, Earle, RW. *Essentials of Strength Training and Conditioning,* 3rd Ed. Champaign, IL: Human Kinetics, 2008.
7. Baker, D, Wilson, G, Carlyon, R. Periodization: The effect on strength of manipulating volume and intensity. *Journal of Strength and Conditioning Research*, 8, 235-242, 1994.

8. Baker, D, Nance, S, Moore, M. The load that maximizes the average mechanical power output during explosive bench press throws in highly trained athletes. *Journal of Strength and Conditioning Research*, 20, 20-24, 2001.
9. Baker, DG, Newton, RU. Methods to increase the effectiveness of maximal power training for the upper body. *National Strength and Conditioning Association*, 27, 24-32, 2005.
10. Bobbert, M, Van Soest, AJ. Effects of muscle strengthening on vertical jump height: A simulation study. *Medicine and Science in Sport and Exercise*, 26, 1012-1020, 1994.
11. Buse, GJ, Santana, JC. Conditioning strategies for competitive kickboxing. *Strength and Conditioning Journal*, 30, 42-48, 2008.
12. Carlock, JM, Smith, SL, Hartman, MJ, Morris, RT, Ciroslan, DA, Pierce, KC, . . . Stone, MH. The relationship between vertical jump power estimates and weightlifting ability: A field test approach. *Journal of Strength and Conditioning Research*, 18, 534-539, 2004.
13. Cronin, J, McNair, PJ, Marshall, RN. Developing explosive power: A comparison of technique training. *Journal of Science and Medicine in Sport*, 4, 59-70, 2001.
14. Cronin, J, Sleivert, G. Challenges in understanding the influence of maximal power training on improving athletic performance. *Sports Medicine*, 35, 213-234, 2005.
15. Docherty, D, Robbins, D, Hodgson, M. Complex training revisited: A review of its current status as a viable training approach. *Strength and Conditioning Journal*, 26, 52-57, 2004.
16. Ebben, WP. Complex Training: A brief Review. *Journal of Sports Science and Medicine*, 1, 42-46, 2002.

17. Fleck, SJ. Periodized strength training: a critical review. *Journal of Strength and Conditioning Research*, 13, 82-89, 1999.

18. Izquierdo, M, Hakkinen, K, Ibanez, J, Garrues, M, Anton, A, Zuniga, A, …Gorostiaga, EM. Effects of strength training on muscle power and serum hormones in middle-aged and older men. *Journal of Applied Physiology*, 90, 1497-1507, 2000.

19. Izquierdo, M, Hakkinen, K, Gonzales-Badillo, JJ, Ibanez, J, Gorostiaga, EM. Effects of long-term training on maximal strength and power of the upper and lower extremities in athletes from different sports. *European Journal of Applied Physiology*, 87, 264-271, 2002.

20. Jamieson, J. *Ultimate MMA Conditioning*. Performance Sports Inc., 2009.

21. Jandacka, D, Vaverka, F. A regression model to determine load for maximum power output. *Sports Biomechanics*, 7(3), 361-371, 2008.

22. Kim, S, Greenwell, TC, Andrew, DPS, Lee, J, Mahony, DF. An analysis of spectator motives in an individual combat sport: A study of mixed martial arts fans. *Sport Marketing Quarterly*, 17, 109-119, 2008.

23. Komi, PV. *Strength and Power in Sport*. Malden, MA: Blackwell Science, Inc., 2004.

24. Ludin, P, Berg, W. A review of plyometric training. *National Strength and Conditioning Association Journal*, 13, 22-30, 1991.

25. Moir, G, Button, C, Glaister, M, Stone, MH. Influence of familiarization on the reliability of vertical jump and acceleration sprinting performance in physically active men. *Journal of Strength and Conditioning Research*, 18, 276-280, 2004.

26. Penn, BJ, Cordoza, G, Krauss, E. *Mixed Martial Arts: The Book of Knowledge*. California: Victory Bell Publishing, 2007.

27. Peterson, MD, Alvar, BA, Rhea, MR. The contribution of maximal force production to explosive movement among young collegiate athletes. *Journal of Strength and Conditioning Research*, 20, 867-873, 2006.
28. Rooney, M. *Training for Warriors*. New York, NY: HarperCollins Publishers, 2008.
29. Rooney, M. *Ultimate Warrior Workouts*. New York, NY: HarperCollins Publishers, 2010.
30. Siff, MC. *Supertraining*, 5th Ed. Denver, CO: Supertraining Institute, 2000.
31. Stone, MH, Moir, G, Glaister, M, Sanders, R. How much strength is necessary? *Physical Therapy in Sport*, 3, 88-96, 2002.
32. Stone, MH, O'Bryant, HS, McCoy, L, Coglianese, R, Lehmkuhl, M, Schilling, B. Power of maximum strength relationships during performance of dynamic and static weighted jumps. *Journal of Strength and Conditioning Research*, 17, 140-147, 2003.
33. Turner, AN. Strength and conditioning for Muay Thai athletes. *Strength and Conditioning Journal*, 31, 78-92, 2009.
34. Wisloff, U, Castagna, C, Helgerud, J, Jones, R, Hoff, J. Strong correlation of maximal squat strength with sprint performance and vertical jump height in elite soccer players. *British Journal of Sports Medicine*, 38, 285-288, 2004.

CHAPTER 4

[2]Prediction between Performance Measures and Mixed Martial Arts Techniques

Clay Walker, Michael Horvat, Bryan McCullick, Jonathan Templin, Michael Ferrara, Adam Singer

Movement Studies Laboratory, Department of Kinesiology, University of Georgia, Athens, Georgia

[2] To be submitted to The Journal of Strength and Conditioning Research

Abstract

Purpose: The purpose of this study was to determine if the components of the NSCA performance index can be used to predict peak power in 3 commonly used mixed martial arts techniques. **Methods:** Male mixed martial artists (n=19) were assessed for the peak power of the cross, rear knee, and double leg takedown. As part of a larger study, there strength measures (1RM deadlift and 1RM bench Press) and power measurements (vertical jump and 60% 1RM bench press) were also assessed. During these assessments, they were also tested in the 10 yard sprint and pro agility shuttle. The participants were tested after week 4 and week 8 of a strength training program. **Results:** The results indicate that only the vertical jump could be used to predict the cross (p=.09). None of the other tests were significant in predicting power with any of the 3 techniques. **Conclusion:** The results in the present study suggest that the performance index be modified to accommodate more specific movements in mixed martial arts.

INTRODUCTION

The origins of mixed martial arts (MMA) have been traced to the ancient Greek sport of pankration (10). The literal translation of pankration is "all powers" and was a mixture of Hellenic boxing and wrestling involving close quarters combat between 2 participants. The influence of pankration into the Greek ethos of strengthening the mind, body and spirit lead to its inclusion in the Olympic Games in 649 B.C. Modern MMA is a summation of various fighting styles including boxing, wrestling, Muay Thai, kickboxing, judo and Brazilian Jui Jitsu and has hit main stream popularity over the past ten years (10). The recent rise in MMA popularity has lead to several major organizations including Ultimate Fighting Championship (UFC), MMA's biggest arena.

This skill and knowledge of MMA is utilized in a very unpredictable combination of very short bursts of high intensity. This sport is very unpredictable and requires the athletes to prepare for multiple aspects of physical combats that include striking, takedowns and the defense of takedowns, grappling, clinching, conditioning/muscle endurance, and strength and power (1). An MMA athlete is often trained in many disciplines of martial arts. Often an MMA fighter accomplishes a mastery of their various movements by being trained in kickboxing and Muay Thai, as well as wrestling and Brazilian Jui Jitsu. Successful participants in MMA need to be well versed in multiple techniques before they enter a high level of competition.

Success in many sports appears to rely heavily upon the participant possessing an adequate degree of various physical qualities such as strength, power, speed, and agility as well as individual skills to participate in the sport of choice. Different strength and conditioning specialists and coaches attempt to predict the functional performance of an athlete through different physical characteristics that include vertical jump, speed, and agility tests (5,6,8). The

characteristics are different depending on the demands of the sport. For instance, the physical characteristics between soccer forward and an American football offensive lineman will be different because their anthropometric and physiological demands differ in response to their sport; therefore, the outcome of certain performance tests, such as, the vertical jump, pro agility shuttle and 10 yard sprint, should be different considering the sport and the athlete.

The correlation between the vertical jump, agility, and sprint has been shown to have strong positive correlations with power and strength (3,9,21). Coaches and scientists have used the vertical jump as a test of lower body power and demonstrated significant correlations with maximal power and strength in many types of athletics. Studies that investigate the correlation between jumping ability and maximal power and strength (3), correlations between maximal force production and explosive ability tested through the vertical jump (16), and the vertical jump training and its effects on improving athletic performance (4) have been investigated and demonstrate the positive effects and significant correlations the vertical jump has as a predictor of power and strength and as a way to improve athletic performance. In addition a running test such as a sprint has often been used as another predictor of power and strength (7,14) in athletes and more often than not, it is studied with the vertical jump (4,21), agility (2), or both (5,9,16). Further, agility has been used as a predictor of power and is usually studied as a combination with vertical jump and sprint abilities (2,5,9,16). In contrast, agility has also been investigated and been considered to be a poor indicator of power (13,17).

Coaches and scientists have used performance tests that involve agility, speed and power as a way of predicting athletic ability in many sports (3,5,7,9,14,16,21). Elite athletes in their respective sport usually have more power, speed, agility and/or strength than their counterparts and should be a predictor of how well an athlete can compete at a certain level.

METHODS

Experimental Approach to the Problem

The purpose of this study was to identify the relationship between the NSCA Performance Index (vertical jump, 10 yard sprint and pro agility shuttle) and three commonly used techniques in MMA; cross, rear knee, and double leg takedown. The NSCA Performance Index is a scoring system based on the results of age, gender, vertical jump, pro-agility shuttle, and the 10-yard sprint that is used to predict the functional ability of an athlete. It was developed to provide athletes with a baseline for performance and symbolize the primary factors in advanced sport performance. Being able to predict the functional performance of an athlete through field testing has been the goal of many coaches and sport scientists.

Subjects

Twenty-five male (19-34 years) mixed martial artists were recruited from the intermediate and advanced MMA class at The HardCore Gym in Athens, GA; however, only 19 subjects would be able to complete the entire study due to injuries that occurred during skills practice sessions. The owner of The HardCore Gym and the instructor of the intermediate and advanced classes identified potential participants who demonstrated a master level of performance in the cross, rear knee, and double leg takedown. Additional inclusion criteria include having participated in MMA for at least two years and participating in the intermediate or advanced classes at The HardCore Gym for at least three months to ensure the athletes had a solid skill and knowledge base to perform the techniques correctly and consistently. The participants practiced their MMA skills a minimum of 3 times and a maximum of 5 times a week throughout the study. They also participated in the investigation 3 days a week for a total of 6-8 training sessions a week. The study was approved by the University of Georgia's Institutional

Review Board and each participant signed an informed consent form approved by the Georgia Institutional Review Board.

Instrumentation

The Tendo Power and Speed Analyzer (Tendo PSA310) made by Tendo Sports Machines (Tendo Unit, Slovak Republic), consists of two functional components; the velocity sensor unit and a microcomputer. The velocity sensor is mounted on the metal pole of a Vertec to ensure proper height adjustment for measurement of the techniques. The velocity sensor unit is connected to a belt by means of a Kevlar cable with a Velcro strap and is connected to the microcomputer via a VSU cable. The Velcro strap connects securely around the belt of the main point of movement for each technique. The outcome measures of the Tendo Unit are peak and average power, measured in watts (W), and peak and average velocity, measured in meters per second (m/s). Weight, in kilograms, and filter, proposed length of movement set at 35cm, is entered into the microcomputer before testing begins. A Pearson Correlation was also used to determine the test-retest reliability of this instrument. The correlation shows a high positive correlation for the cross (0.96), the rear knee (0.88), and the double leg takedown (0.90). The unit was calibrated at the factory to ensure its accuracy in detecting the speed and force used by these participants. In addition, the unit was verified by the UGA Department of Engineering that it measures muscle power generated by electrical power through the detection of movement.

The performance index was developed by the NSCA to quantify power, agility and speed in athletes. It was a scoring system based on the results of the vertical jump, pro-agility shuttle, and 10 yard sprint combined with age and gender. The index was designed to score each participant in a percentile ranking based on each performance. The final score was the average of the three percentiles and has been developed for specific age groups.

Procedures

Three data points were used for testing; pre-testing, 4 weeks and 8 weeks. Pre-testing assessments of power and strength occurred across three days to decrease fatigue, risk of injury, and allow optimal performance. On the first day of testing, the weight of each participant was collected, and then a warm-up period was provided. Following the warm-up, each participant was introduced to the Tendo Unit and provided an opportunity to become familiar with the unit by practicing no more than 10-30 repetitions of each movement. During this time the researcher adjusted the Tendo Unit for comfort and accuracy and answered any questions. The velocity sensor unit of the Tendo Unit was mounted on the metal pole of a Vertec and adjusted in height before each technique was performed. The pole was placed 12 inches behind the participant to ensure safety. For the cross, the strap of the Kevlar cable was placed around the distal end of the radius and ulna and the Tendo was adjusted so the cable exit was even with the shoulder. For the rear knee, the strap was placed around the femur in line with the superior aspect of the patella and for the double leg takedown; the strap was placed around the trunk in line with the iliac crest and PSIS. Once the strap was placed in the proper position the sensor height was adjusted on the Vertec pole to be level with the strap placement. Each power and velocity measurement was recorded after each repetition of each technique. For the cross, the participant wore a four ounce MMA glove. The outcome values included peak power for the 3 MMA techniques.

Forty-eight hours after the first day of testing, each participant performed the components of the NSCA Performance Index which includes vertical jump (height measured in inches), pro-agility shuttle (agility measured in seconds), and 10 yard sprint (speed measured in seconds). After a warm-up period, the test began with the vertical jump. The participant stepped under the vanes of the Vertec and reached as high as possible until the finger tips of the dominant hand

touch the bottom vane. Then, three jumps were allowed to reach maximum height and that score was recorded. The pro-agility shuttle was performed after the vertical jump. The participant performed two warm-up trails before performing three trials that were averaged for time. The 10 yard sprint was performed last and each participant was allowed two warm-up trials before performing three trials that were averaged for time. The outcomes for day two testing were the lower body power, agility and speed of each participant. As part of a larger study, a third testing day occurred that was non significant to this study.

An eight week, three times per week, strength and conditioning intervention aimed at improving the power and strength of each individual occurred at The HardCore Gym. The program was designed to add strength and power through proper periodization, volume, and intensity. It was based on the three principles of program design in strength and conditioning: 1) specificity, 2) overload, and 3) progression. The program was designed by a certified strength and conditioning coach with 12 years experience as a Division I college strength and conditioning coach.

The strength and conditioning intervention lasted eight weeks and each participant had three training sessions each week. Each training session lasted approximately 50 minutes, and the same exercises were performed on the same day each week. A certified strength and conditioning coach with 12 years experience will be present each training session for each participant.

Statistical Analysis

The purpose of this analysis was to determine the correlation between peak power measures in 3 commonly used MMA techniques and the components of the NSCA performance index. The MMA techniques used were the cross (PPC), rear knee (PPK), and double leg

takedown (PP2DL) along with the components of the NSCA performance index: vertical jump (VJ), 10 yard sprint (10YD), and the pro agility shuttle (SS). The PPC, PPK, and PP2DL were recorded at three different times during the course of an 8 week strength and conditioning intervention designed to increase strength and power in the lower and upper body as well as improve speeds in the 10YD and SS. A hierarchical linear model was used to control for the dependency because of the repeated measures. For this analysis, SAS 9.2 (Cary, NC) was used to analyze the data and the alpha level was set at $\alpha=0.1$.

RESULTS

The increases in peak power for each of the 3 MMA techniques can be seen in Table 4.1 (pg.16) and the percent increase can be seen in Table 4.2 (pg. 16). The change in the NSCA components can be seen in Table 4.3 (pg.16) and the percent change can be seen in Table 4.4. Figure 4.1 (pg. 17), Figure 4.2 (pg. 18), and Figure 4.3 (pg. 19) show the positive increase in power through time for the PPC, PPK and the PP2DL, respectively.

A hierarchical regression analysis was fit to look at the significance of each of the component of the NSCA performance index and the (VJ, 10YD, and SS) and the correlation to the significant increase in peak power of the cross (PPC), rear knee (PPK), and double leg takedown (PP2DL). The grand mean average was taken for each of the variables and the analysis determined that only the grand mean average of the vertical jump ($p=0.09$) was the only variable significant to the PPC. The statistics indicate that for every inch improved in the vertical jump, the power of the cross would increase by 299.4 W. No other variables showed any significance in correlation or predictive value in any of the other techniques (PPK and PP2DL).

In conclusion, the analysis determined that there was an increase in the performance components of the NSCA (VJ, 10YD and SS) and the MMA techniques (PPC, PPK and PP2DL)

throughout the testing periods; however there was only one correlation between the assessments (VJ, 10YD and SS) and the peak power outputs of the 3 MMA techniques (PPC, PPK and PP2DL). The only correlation was between the VJ ($p=0.09$ and $\beta=299.4$) and PPC.

DISCUSSION

The purpose of the current investigation was to determine if the components of the NSCA performance index sustained any predictive ability with 3 common techniques in MMA. Statistically, only the vertical jump was a significant predictor to the cross ($p=0.09$). No other variable was significant for any of the remaining two techniques.

The components of the NSCA performance index, vertical jump, 10 yard sprint and pro agility shuttle and tests like them, in some way have been used in other sports to predict performance in power (9,18), strength (19,21), and/or functional settings (2,6). Coaches and scientists have often made attempts to determine athlete performance by using other functional tests, like those of the NSCA performance index. However, investigations among athletes in certain sports have concluded that these components, and those like them, do not predict any performance measure while other investigations render evidence that they can be used as predictors of athletic performance.

The results of this investigation are supported by findings in other investigations that found no correlation between one or more of these components (11,13,17). Kuzmits and Adams (11) investigated the correlation between the (National Football League) NFL combine test results and NFL success for players drafted as offensive skill players (quarterback, wide receiver and running back) over a 6 year period. The NFL combine consists of physical drills like those performed in the NSCA performance index with the addition more agility drills, strength exercises, player position drills, interviews, and aptitude tests. By using correlation analysis, the

investigators found no relationship between combine tests and professional football performance, with the exception of sprint tests for running backs. This provides evidence to question the overall usefulness of the tests used at the combine to evaluate talent. Therefore, we can provide evidence that the current investigation has found similar results where only one component of the NSCA performance index could be used as a predictor of peak power in the cross and none of the other techniques.

Another study that provides evidence for the results of the current investigation is the work of Markovic (13). He designed a study that used 76 male physical education students that performed 3 agility tests that consisted of lateral stepping, pro agility shuttle (used in the current investigation) and the slalom run. Strength (isoinertial squat, isometric squat and one-leg rising) and power tests (squat jump power, hopping power and standing long jump distance) were obtained to correlate with the agility tests. The study determined that the correlation between strength and power and the agility tests were generally low. The correlation coefficient for the pro agility shuttle ($r=0.44$) was the highest to correlate with any of the power and strength measures.

This current investigation found only the vertical jump to be a predictor of peak power in the cross. The vertical jump has been used to significantly predict power in other investigations (2,4). This provides evidence that the vertical jump can be used as a predictor of peak power as a performance measure for the cross. Another way to provide evidence of this finding is to look at the steps in performing the cross correctly. The cross is a punch thrown with the dominate hand and is used by many MMA athletes as a power punch (15). The main point of the movement that determines the power of the punch is the force applied to the ground by the rear leg as the hips are rotating forward (20). This same force is applied to the ground before takeoff

in the vertical jump (12). This could explain the predictive ability in the relationship between the vertical jump and the cross.

Another explanation for the findings of this investigation could be the nature of the sport. Most of the tests like the ones used in the NSCA performance index are studied in sports that could be considered linear and lateral sports such as football, soccer and basketball. The sport of MMA is very different in terms of movement and requires the athlete to move in short compact movements. These movements do not expand over a range of 5, 10, or 20 yards but only a few feet at the time. Therefore, these types of assessments could be irrelevant to the sport of MMA and the predictions of power or any other measurement. Because the assessments are irrelevant we conclude that the skill expertise in of MMA can not correlate with performance skills that are used in other sports.

Conclusion

The ability of certain movements or exercises to predict performance in an athlete has been studied extensively. This study investigated the ability of the components of the NSCA performance index to predict peak power in 3 commonly used techniques in MMA. The study determined that only the vertical jump can be used to predict peak power in the cross. No other component was significant in determining peak power in the cross, rear knee or the double leg takedown and these findings are supported by other research that try to use these types of field tests to determine some type of performance measure.

Future studies that try to predict peak power, or any other measure in MMA, should use other components that emulate the movement in MMA. For example, upper body movements are not assessed in the performance index and cannot accommodate more specific movement in MMA. A medicine ball punch could be used as a measure of upper body power and added to a

more accurate index that would predict power. Further the speed or agility can be modified to measure explosiveness and quickness in a smaller area. It is also possible that the next study could have more significant measures if the population size was larger. The population depleted by n=6 subjects throughout the study because of injuries sustained during regular skills practice. Had these subjects been able to complete the study, the study would have had more statistical power and the results of the study could have been different enough to show more significant variables in relation to prediction power of the components of the NSCA performance index.

Future studies in the sport of MMA, as it pertains to strength and conditioning, should also involve investigations in energy system use in MMA, the benefits of increases or decreases in the number of training sessions an MMA athlete has while preparing for a competition, the duration a MMA athlete should take to prepare for a competition, and overtraining issues in MMA. All these areas need to be studied by scientist and coaches of MMA to ensure that these athletes are training the best possible way for competition.

PRACTICAL APPLICATION

Strength and conditioning coaches need to understand how unique the sport of MMA really is. The principles of the longitudinal and lateral sports (e.g. football, soccer, and basketball) can't be applied to this sport. Designing a test to help predict performance in MMA athletes may need to be based more on the movements of the sport; therefore, shorter more compact components that include movements designed to test upper and lower body strength and power could to be utilized to create a test that would be more conducive to predicting performance in MMA athletes.

Table 4.1 Increase in Peak Power of Mixed Martial Arts Techniques

Technique	Pre-test	Mid-test	Post-test
Cross	5025.5 W	5185 W	5325 W
Rear Knee	2400 W	3001 W	5401 W
Double Leg	1852 W	1895 W	1988 W

Table 4.2 Percent Increase in Mixed Martial Arts Techniques from Pre-test through Post-test

Technique	Pre-test to Mid-test	Mid-test to Post-test	Overall
Cross	2.60%	3.80%	6.50%
Rear Knee	25%	79%	125%
Double Leg	2%	4%	7.50%

Table 4.3 Change in NSCA Components

Assessment	Pre-test	Mid-test	Post-test
Vertical Jump	23.5 in	24.5 in	25.25 in
10 Yard Sprint	1.9 s	1.8 s	1.7 s
Pro Agility Shuttle	5.3 s	5.2 s	5.1 s

Table 4.4 Percent Change in NSCA Components

Assessment	Pre-test to Mid-test	Mid-test to Post-test	Overall
Vertical Jump	4.25%	3%	7.40%
10 Yard Sprint	-5%	-5.50%	-10%
Pro Agility Shuttle	-4%	-2%	-6%

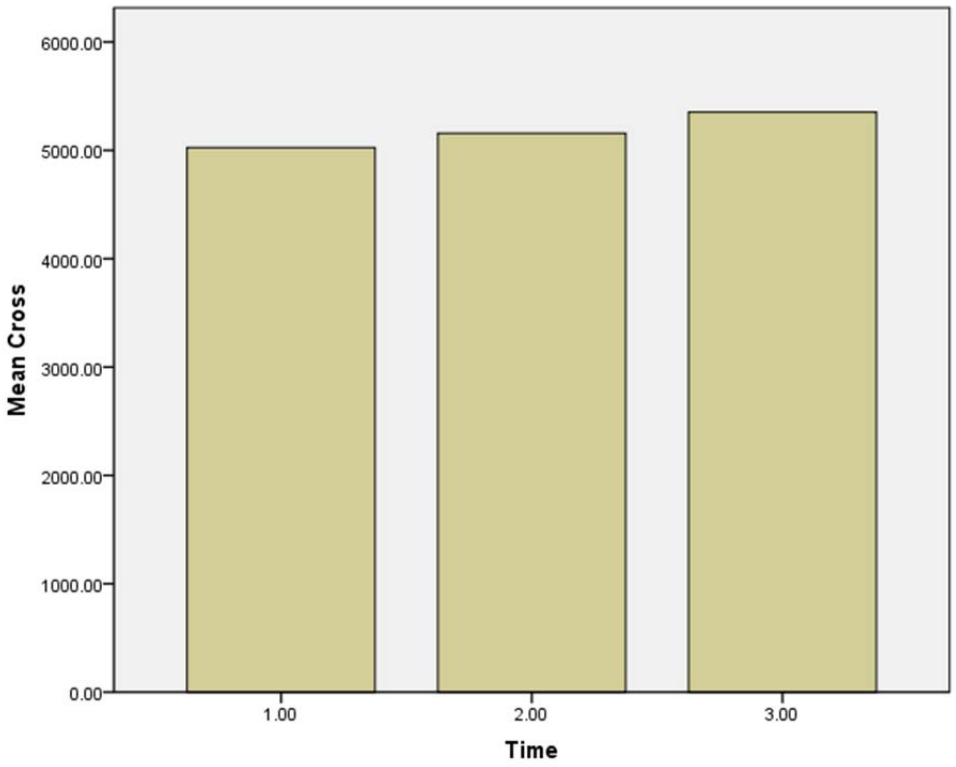

Figure 4.1 Increases in the Peak Power of the Cross over Time

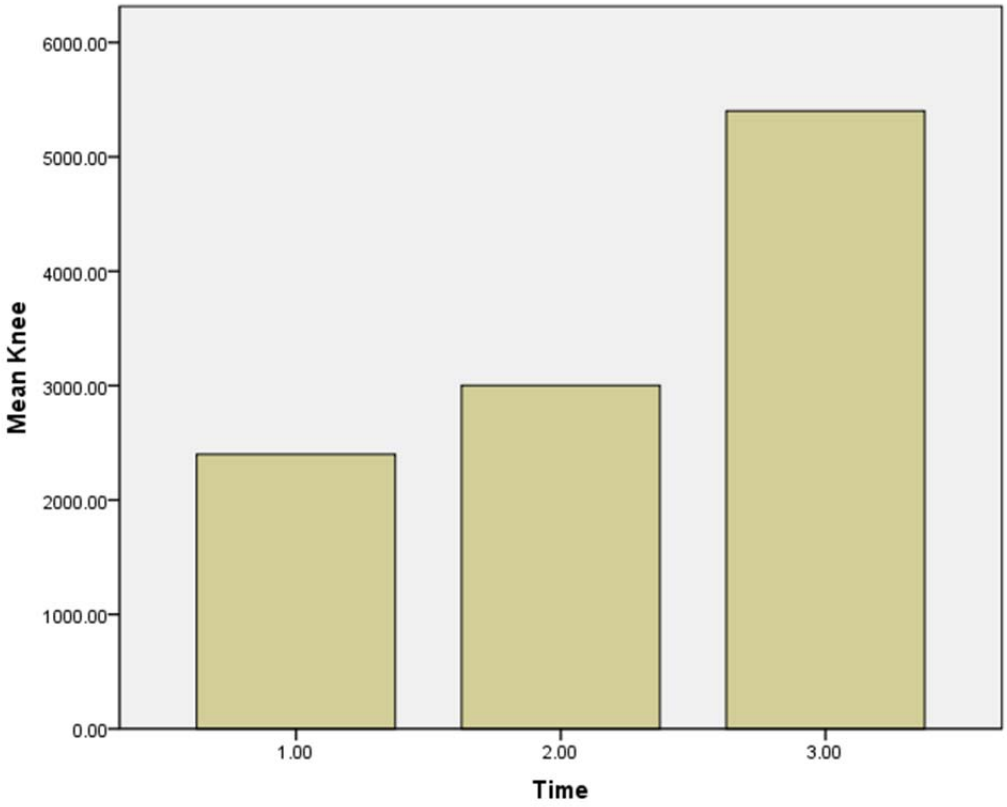

Figure 4.2 Increases in Peak Power of the Rear Knee over Time

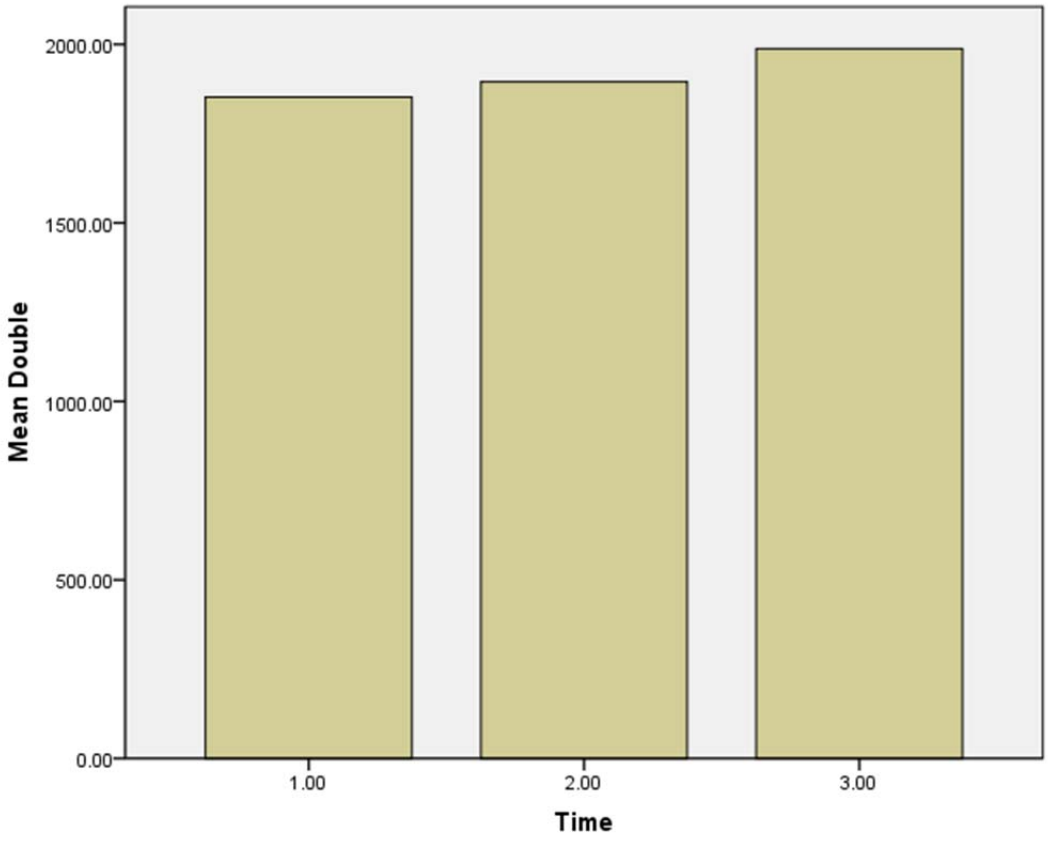

Figure 4.3 Increases in Peak Power of the Double Leg Takedown over Time

References

1. Amtmann, JA. Self-Reported Training Methods of Mixed Martial Artists at a Regional Reality Fighting Event. *Journal of Strength and Conditioning Research*, 18(1), 194-196, 2004.
2. Baker, DG, Newton, RU. Comparison of lower body strength, power, acceleration, speed, agility, and sprint momentum to describe and compare playing rank among professional rugby league players. *Journal of Strength and Conditioning Research*, 22, 153-158, 2008.
3. Carlock, JM, Smith, SL, Hartman, MJ, Morris, RT, Ciroslan, DA, Pierce, KC, Newton, RU, Harman, EA, Sands, WA, Stone, MH. The relationship between vertical jump power estimates and weightlifting ability: A field test approach. *Journal of Strength and Conditioning Research*, 18, 534-539, 2004.
4. Cronin, J, Sleivert, G. Challenges in understanding the influence of maximal power training on improving athletic performance. *Sports Medicine*, 35, 213-234, 2005.
5. Davis, DS, Barnette, BJ, Kiger, JT, Mirasola, JJ, Young, SM. Physical characteristics that predict functional performance in Division I college football players. *Journal of Strength and Conditioning Research*, 18, 115-120, 2004.
6. Gabbett, TJ. Influence of physiological characteristics on selection in a semi-professional first grade rugby league team: a case study. *Journal of Sports Sciences*, 20, 399-405, 2002.

7. Harris, NK, Cronin, JB, Hopkins, WG, Hansen, KT. Relationship between sprint times and the strength/power outputs of a machine squat jump. *Journal of Strength and Conditioning Research*, 22, 691-698, 2008.
8. Hoare, DG, Warr CR. Talent identification and women's soccer: An Australian experience. *Journal of Sports Science*, 18, 751-758, 2002.
9. Hori, N, Newton, RU, Andrews, WA, Kawamori, N, McGuigan, MR, Nosaka, K. Does the performance of hang clean differentiate performance of jumping, sprinting, and changing of direction? *Journal of Strength and Conditioning Research*, 22, 412-418, 2008.
10. Kim, S, Greenwell, TC, Andrew, DPS, Lee, J, Mahony, DF. An Analysis of Spectator Motives in an Individual Combat Sport: A Study of Mixed Martial Arts Fans. *Sport Marketing Quarterly*, 17, 109-119, 2008.
11. Kuzmits, FE, Adams, AJ. The NFL Combine: Does it predict Performance in the National Football League? *Journal of Strength and Conditioning Research*, 22, 1721-1727, 2008.
12. Linthorne, NP. Analysis of standing vertical jumps using the force platform. *American Journal of Physics*, 69, 1198-1204, 2001.
13. Markovic, G. Poor relationship between strength and power qualities and agility performance. *Journal of Sports Medicine and Physical Fitness*, 47, 276-283, 2007.
14. McBride, JM, Blow, D, Kirby, TJ, Haines, TL, Dayne, AM, Triplett, NT. Relationship between maximal squat strength and five, ten, and forty yard sprint times. *Journal of Strength and Conditioning Research*, 23, 1633-1636, 2009.

15. Penn, BJ, Cordoza, G, Krauss, E. *Mixed Martial Arts The Book of Knowledge*. California: Victory Bell Publishing, 2007.
16. Peterson, MD, Alvar, BA, Rhea, MR. The contribution of maximal force production to explosive movement among young collegiate athletes. *Journal of Strength and Conditioning Research*, 20, 867-873, 2006.
17. Sheppard, JM, Young, WB. Agility literature review: Classifications, training and testing. *Journal of Sport Science*, 24, 919-932, 2006.
18. Stone, MH, Moir, G, Glaister, M, Sanders, R. How much strength is necessary? *Physical Therapy in Sport*, 3, 88-96, 2002.
19. Stone, MH, O'Bryant, HS, McCoy, L, Coglianese, R, Lehmkuhl, M, Schilling, B. Power of Maximum strength relationships during performance of dynamic and static weighted jumps. *Journal of Strength and Conditioning Research*, 17, 140-147, 2003.
20. Walker, CH, Horvat, M, Mccullick, BA, Templin, J, Ferrara, M, Singer, A. *Effects of an eight week training intervention on peak power in mixed martial arts techniques* (Unpublished doctoral dissertation). University of Georgia, Athens, GA., 2011.
21. Wisloff, U, Castagna, C, Helgerud, J, Jones, R, Hoff, J. Strong correlation of maximal squat strength with sprint performance and vertical jump height in elite soccer players. *British Journal of Sports Medicine*, 38, 285-288, 2004.

CHAPTER 5

CONCLUSIONS

MMA continues to grow in popularity around the world. Strength and conditioning programs developed to increase performance in these athletes will become very important as the sport continues to evolve. In MMA, the primary objective is the submission of one's opponent accomplished through various takedowns and locks or even by knockout blows using the hands, knees, and feet. In order to accomplish a submission or knockout, two underlying principles of MMA, therefore, are power and strength. The more forceful a participant can punch, kick, grapple or knee, the more strength and speed the athlete ultimately possesses that increases the chances for a successful performance and victory.

Two individual studies were completed during this investigation and each involved the peak power of 3 commonly used techniques in MMA; cross, rear knee and double leg takedown. The first study investigated the relationship between increases in strength and power after an 8 week strength and conditioning intervention and peak power in the 3 techniques and found that an increase in strength and power could increase peak power in MMA techniques. It also found that MMA athletes do not utilize exercises that increase lower body strength and power as well. This was evident in the large increase in strength and power and the vast increase in rear knee peak power throughout the study. The study also provided the relationships of the increases in strength and power that were responsible for the increase in peak power for each technique.

The second study examined the predictive ability between the vertical jump, 10 yard sprint, and pro agility shuttle with the peak power of the 3 techniques. The significant variables in the first study were explained through the dynamics of each technique. The second study

revealed no conclusive evidence that any of the field test variables were able to able to predict power in any of the 3 techniques with the exception of the vertical being able to significantly able to predict peak power in the cross.

The research in strength and conditioning in the field of MMA using its athletes as the participants is novel. Studies could investigate anything from the use of energy systems during a competition to the importance of flexibility in MMA. The investigators of this study feel the very near research in these fields should include but are not limited to investigations in the use of the energy systems and their role during an MMA competition, the relationship between increases in peak power in these 3 techniques after an 8 week Olympic weightlifting program and a study based on overtraining and its symptoms and implications. This would give the coaches and athletes a better understanding of how to train the body for a competition and give them guidelines to train with and help the overall performance of the athlete and prevent injury.

References

Aagaard, P., Simonsen, E.B., Andersen, J.L., Magnusson, P., Dyhre-Poulsen, P. (2002). Increase rate of force development and neural drive of human skeletal muscle following resistance training. *Journal of Applied Physiology*, 93, 1318-1326. doi: 10.1152/japplphysiol.00283.2002

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

Amtmann, J.A. (2004). Self-Reported Training Methods of Mixed Martial Artists at a Regional Reality Fighting Event. *Journal of Strength and Conditioning Research*, 18(1), 194-196.

Amtmann, J.A., Amtmann, K.A., Spath, W.K. (2008).Lactate and Rate of Perceived Exertion Responses of Athletes Training for and Competing in a Mixed Martial Arts Event. *Journal of Strength and Conditioning Research*, 22(2), 645-647.

Amtmann, J. (2010). High Intensity Training and the Mixed Martial Artist. In J.E. Warnick (Ed.), *Advancements in the Scientific Study of Combative Sports.* (pp.13-39). © 2010 Nova Science Publishers, Inc.

Baechle, T.R., Earle, R.W. (2008). *Essentials of Strength Training and Conditioning,* 3rd Ed. Champaign, IL: Human Kinetics.

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

Baker, D., Nance, S., Moore, M. (2001). The load that maximizes the average mechanical power output during explosive bench press throws in highly trained athletes. *Journal of Strength and Conditioning Research*, 20, 20-24.

Baker, D.G., Newton, R.U. (2005). Methods to increase the effectiveness of maximal power training for the upper body. *National Strength and Conditioning Association*, 27, 24-32.

Baker, D.G., Newton, R.U. (2008). Comparison of lower body strength, power, acceleration, speed, agility, and sprint momentum to describe and compare playing rank among professional rugby league players. *Journal of Strength and Conditioning Research*, 22, 153-158.

Bledsoe, G.H., Hsu, E.B., Grabowski, J.G., Brill, J.D., Li, G. (2006). Incidence of Injury in Professional Mixed Martial Arts Competitions. *Journal of Sports Science and Medicine,* CSSI, 136-142.

Bobbert, M., Van Soest, A.J. (1994). Effects of muscle strengthening on vertical jump height: A simulation study. *Medicine and Science in Sport and Exercise*, 26, 1012-1020.

Buse, G.J., Santana, J.C. (2008). Conditioning strategies for competitive kickboxing. *Strength and Conditioning Journal*, 30, 42-48.

Carlock, J.M., Smith, S.L., Hartman, M.J., Morris, R.T., Ciroslan, D.A., Pierce, K.C., Newton, R.U., Harman, E.A., Sands, W.A., Stone, M.H. (2004). The relationship between vertical jump power estimates and weightlifting ability: A field test approach. *Journal of Strength and Conditioning Research*, 18, 534-539.

Cronin, J., McNair, P.J., Marshall, R.N. (2001). Developing explosive power: A comparison of technique training. *Journal of Science and Medicine in Sport*, 4, 59-70.

Cronin, J., Sleivert, G. (2005). Challenges in understanding the influence of maximal power training on improving athletic performance. *Sports Medicine*, 35, 213-234.

Davis, D.S., Barnette, B.J., Kiger, J.T., Mirasola, J.J., Young, S.M. (2004). Physical characteristics that predict functional performance in Division I college football players. *Journal of Strength and Conditioning Research*, 18, 115-120.

Docherty, D., Robbins, D., Hodgson, M. (2004). Complex training revisited: A review of its current status as a viable training approach. *Strength and Conditioning Journal*, 26, 52-57.

Ebben, W.P. (2002). Complex Training: A brief Review. *Journal of Sports Science and Medicine*, 1, 42-46.

Fleck, S.J. (1999). Periodized strength training: a critical review. *Journal of Strength and Conditioning Research*, 13, 82-89.

Gabbett, T.J. (2002). Physiological characteristics of junior and senior rugby league players. *British Journal of Sports Medicine*, 36, 334-339.

Gabbett, T.J. (2010). Influence of physiological characteristics on selection in a semi-professional first grade rugby league team: a case study. *Journal of Sports Sciences*, 20, 399-405.

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

Glassman, G. (2003). Metabolic conditioning. *Crossfit Journal Articles*, 10, 1-4.

Hakkinen, K. (1994). Neuromuscular adaptation during strength training, aging, detraining, and immobilization. *Critical Reviews in Physical and Rehabilitation Medicine*, 6, 161-198.

Harris, G.R., Stone, M.H., O'Bryant, H.S., Proulx, C.M., Johnson, R.L. (2000). Short-term performance of high power, high force, and combined weight-training methods. *Journal of Strength and Conditioning Research*, 14, 14-20.

Harris, N.K., Cronin, J.B., Hopkins, W.G., Hansen, K.T. (2008). Relationship between sprint times and the strength/power outputs of a machine squat jump. *Journal of Strength and Conditioning Research*, 22, 691-698.

Hoare, D.G., Warr C.R. (2002). Talent identification and women's soccer: An Australian experience. *Journal of Sports Science*, 18, 751-758.

Hori, N., Newton, R.U., Andrews, W.A., Kawamori, N., McGuigan, M.R., Nosaka, K. (2008). Does the performance of hang clean differentiate performance of jumping, sprinting, and changing of direction? *Journal of Strength and Conditioning Research*, 22, 412-418.

Izquierdo, M., Hakkinen, K., Ibanez, J., Garrues, M., Anton, A., Zuniga, A., Larrion, J.L., Gorostiaga, E.M. (2000). Effects of strength training on muscle power and serum hormones in middle-aged and older men. *Journal of Applied Physiology*, 90, 1497-1507.

Izquierdo, M., Hakkinen, K., Gonzales-Badillo, J.J., Ibanez, J., Gorostiaga, E. M. (2002). Effects of long-term training on maximal strength and power of the upper and lower extremities in athletes from different sports. *European Journal of Applied Physiology*, 87, 264-271. doi: 10.1007/s00421-002-0628-y

Jamieson, J. (2009). *Ultimate MMA Conditioning*. Performance Sports Inc.

Jandacka, D., Vaverka, F. (2008). A Regression Model to Determine Load for Maximum Power Output. *Sports Biomechanics*, 7(3), 361-371.

Kim, S., Greenwell, T.C., Andrew, D.P.S., Lee, J., Mahony, D.F. (2008). An Analysis of Spectator Motives in an Individual Combat Sport: A Study of Mixed Martial Arts Fans. *Sport Marketing Quarterly*, 17, 109-119.

Komi, P.V. (Ed.). (2004). *Strength and Power in Sport*. Malden, MA: Blackwell Science, Inc.

Kuzmits, F.E., Adams, A.J. (2008). The NFL Combine: Does it predict Performance in the National Football League? *Journal of Strength and Conditioning Research*, 22, 1721-1727.

La Bounty, P., Campbell, B.I., Galvan, E., Cooke, M., Antonio, J. (2011). Strength and conditioning considerations for mixed martial arts. *Strength and Conditioning Journal*, 33, 56-67.

Linthorne, N.P. (2001). Analysis of standing vertical jumps using the force platform. *American Journal of Physics*, 69, 1198-1204.

Ludin, P., Berg, W. (1991). A review of plyometric training. *National Strength and Conditioning Association Journal*, 13, 22-30.

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

Markovic, G. (2007). Poor relationship between strength and power qualities and agility performance. *Journal of Sports Medicine and Physical Fitness*, 47, 276-283.

Moir, G., Button, C., Glaister, M., Stone, M.H. (2004). Influence of familiarization on the reliability of vertical jump and acceleration sprinting performance in physically active men. *Journal of Strength and Conditioning Research*, 18, 276-280.

Penn, B.J., Cordoza, G., Krauss, E. (2007). *Mixed Martial Arts The Book of Knowledge*. California: Victory Bell Publishing.

Perez-Gomez, J., Olmedillas, H., Delgado-Guerra, S., Ara Royo, I., Vicente-Rodriguez, G., Arteaga Ortiz, R., Chavarren, J., Calbet, J.A.L. (2008). Effects of weight lifting training combined with plyometric exercises on physical fitness, body composition, and knee extension velocity during kicking in football. *Applied Physiology, Nutrition, and Metabolism*, 33, 501-510.

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, 867-873.

Potteiger, J.A., Lockwood, R.H., Haub, M.D., Dolezal, B.A., Almuzaina, K.S., Schroeder, J.M., Zebas, C.J. (1999). Muscle Power and Fiber Characteristics Following 8 Weeks of Plyometric Training. *Journal of Strength and Conditioning Research*, 13, 275-279.

Rooney, M. (2008). *Training for Warriors*. New York, NY: HarperCollins Publishers.

Rooney, M. (2010). *Ultimate Warrior Workouts*. New York, NY: HarperCollins Publishers.

Rucci, J.A., Tomporowski, P.D. (2010). Three types of kinematic feedback and the execution of the hang power clean. *Journal of Strength and Conditioning Research*, 24, 771-778.

Siff, M.C. (2000). *Supertraining*, 5th Ed. Denver, CO: Supertraining Institute.

Stone, M.H., Moir, G., Glaister, M., Sanders, R. (2002). How much strength is necessary? *Physical Therapy in Sport*, 3, 88-96.

Stone, M.H., O'Bryant, H.S., McCoy, L., Coglianese, R., Lehmkuhl, M., Schilling, B. (2003). Power of Maximum strength relationships during performance of dynamic and static weighted jumps. *Journal of Strength and Conditioning Research*, 17, 140-147.

Turner, A.N. (2009). Strength and conditioning for Muay Thai athletes. *Strength and Conditioning Journal*, 31, 78-92.

Walker, C.H., Horvat, M., Mccullick, B.A., Templin, J., Ferrara, M., Singer, A. (2011). *Effects of an eight week training intervention on peak power in mixed martial arts techniques* (Unpublished doctoral dissertation). University of Georgia, Athens, GA.

Wisloff, U., Castagna, C., Helgerud, J., Jones, R., Hoff, J. (2004). Strong correlation of maximal squat strength with sprint performance and vertical jump height in elite soccer players. *British Journal of Sports Medicine*, 38, 285-288.