WEIGHT CUTTING:
A BIOMECHANICAL INVESTIGATION OF THE EFFECT ON MARTIAL ARTS STRIKING PERFORMANCE

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Abstract

Weight cutting is a phenomenon that exists in combative weight-class-based sports. The goal of this research was to investigate the effect of weight cutting on striking performance parameters amongst mixed martial arts practitioners. Participants were tested on common strikes using a method specifically developed for the investigation of reaction time, power, and accuracy. These tests were performed prior to a self-selected weight-cut procedure and 24 hours after making weight, with the hypothesis that weight cutting would exhibit a negative effect on the tested parameters. The findings demonstrated a negative effect on peripheral reaction time, a positive effect on central reaction time, and mixed results on power and accuracy. No previous work has been performed on weight cutting and reaction time or accuracy. Future research should look to investigate the phenomenon closer to its real sport setting and to further the investigation of reaction time and accuracy.

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Chapter 1: Introduction

My goal for this chapter is to briefly introduce the phenomenon of weight cutting in sport. I will also present the study purpose, significance, hypothesis, and limitations.

Background/Theme

The sport of mixed martial arts is a free-form, one-on-one combative sport that has its origins in contests attempting to determine which martial art and/or fighting styles were superior. Examples of commonly used styles or disciplines include, but are not limited to, wrestling, boxing, Muay Thai kickboxing, judo, sambo, karate, tae kwon do, and Brazilian jiu-jitsu. Three main areas of empty-handed combat are generally involved: striking/stand up, take downs/throws, and grappling. This sport has developed into a full-contact combat sport with regulations and sanctions, variations of which are becoming popular all over the world. Athletes have shifted from a focus on singular disciplines and have developed into a hybrid mixture of various styles or mixed martial arts. Over the years, the sport of mixed martial arts has become increasingly popular in both spectatorship and participation (Lenetsky & Harris, 2012; Ngai, Levy, & Hsu, 2008; Seidenberg, 2011).

The phenomenon of weight cutting, or cycling, is associated with weight class-based sports where athletes will "choose to reduce their body mass to a weight class lower than their normal weight" (Horswill, 2009, p. 22). This is an intentional body mass reduction prior to a competition's weigh-in and subsequent regain of as much as possible, if not all, of the mass between the weigh-in and the actual competition. Due to the weight class-based nature of mixed martial arts competitions and approximate 24-hour time window between weigh-ins and competition, weight cutting as a practice is deeply embedded in the sport. Athletes who do not make their contracted weight class may be subject to monetary penalty and/or disqualification. The practice of weight cutting is sometimes discussed openly prior to and during competitions as well as in deciding future match ups.

Weight manipulation practices were first mentioned in the 1940s in relation to wrestling, and they are described as having changed little from that time despite the increasing knowledge on the negative effects of such weight loss practices. While weight classes exist to promote fair and matched competition, they also encourage athletes to compete at lower classes in an attempt to increase the chances of success. As there was very limited literature across combat sports, researchers noted the need for further investigations into all areas related to the practice of weight cutting, including: health, longitudinal effects, growth and maturation, performance, psychology, and general success as well as safe practices (Brownell & Steen, 1992; Horswill, 2009; Steen & Brownell, 1990).

Koral and Dosseville (2009) explained the phenomenon of body mass reduction in weight class-based sports, summarizing,

> Most athletes participating in combat sports with specific body mass categories such as wrestling, boxing, and judo can compete in a class 10% below their usual body mass. Thus body mass control may be as important an issue as performance. In sports in which body mass plays a decisive role, the athletes can resort to passive (sauna) and active sweating (through intensive exercise in plastic suits) as well as reducing the amount of food and liquids they consume. Rapid body mass loss (i.e., in 3–4 days) has been reported to be detrimental to performance in terms of power, force, resistance, flexibility, and skilfulness. . . . Moreover, such a procedure may influence cognitive performance and mood negatively. (p. 115)

The limited research across combat sports was not necessarily conclusive, although Horswill (2009) stated that “short-duration high-intensity performance is less likely to be affected adversely. If the effort is extended and repeated, i.e., requires an element of endurance, performance deteriorates. For submaximal efforts of longer duration, performance is clearly impacted in a negative way" (p. 29). This summary demonstrated the need for more research in general and a move from laboratory-based physical performance to sport-specific physical performance studies. It also demonstrated the need to broaden and expand the combative sports studied: an example being that no studies focused on mixed martial artists.

In the position paper on exercise and fluid replacement for the American College of Sports Medicine, Sawka et al. (2007) wrote specifically on boxing and wrestling as examples of weight-based sports at risk for dehydration. They went on to state that "dehydration greater than 2% body weight degrades aerobic exercise and cognitive/mental performance in temperate-warm-hot environments" (p. 381).

The act of weight cutting is not just a performance issue; in its extreme cases, dehydration related to weight cutting may lead to serious medical issues such as heat-related illnesses and stress on the kidneys (Horswill, 2009; Sawka et al., 2007). In 1997, three NCAA wrestlers in different states died from complications associated with dehydration from rapid weight loss procedures (Hoey, 1998; Remick et al., 1998). The Team USA Olympic wrestling captain was barred from competition at the 2008 Beijing Olympics given his deteriorated physical state at the weigh in. He claimed he would be fine at the competition, but physicians barred him from competition (Mihoces, 2008). There was even one alarming case of a 5-year-old wrestler receiving pressure to drop weight (Sansone & Sawyer, 2005). Weight cutting is a very real part of combat sports, and the practice continues today, even in extreme cases, in the presence of modern health and athletic performance knowledge.

Athletes may ignore potential long-term health warnings or threats for a potential increased chance of success. If weight cutting could be shown to decrease athletic performance, prowess, or ability, as well as a potential negative health impact, then the practice might possibly be curtailed.

This lead to the question: What is the influence of a self-selected weight manipulation regimen on biomechanical parameters of martial arts striking performance among mixed martial arts practitioners?

Purpose

The aim of this study was to initiate an investigation on the effect of weight cutting on striking performance within a mixed martial artist population using state-of-the-art biomechanical equipment. Parameters under exploration include 3D kinematics, power, accuracy, reaction time, and balance. Also, no restrictions were placed on subjects' weight-loss protocols; the athletes were allowed to utilize their preferred methods and timing strategies of weight reduction and regain. Such an effort preserved the tested subjects' normal "style" in a competitive preparation and made the results more realistic.

Significance

Through this study, as the researcher, I looked to fill a gap where there has been limited research on weight cutting across combat sports, even less on biomechanical parameters and/or performance, and no existing literature focused on a mixed martial arts population. Only one study to date has allowed the athletes to use their own methods of weight reduction when researcher-imposed methods could be considered the largest barrier to a research consensus (Timpmann, Oopik, Paasuke, Medijainen, & Ereline, 2008).

The research as carried out in the University of Lethbridge Biomechanics Lab in the Kinesiology Department over a one-year period between May 2009 and December 2011. A portion of the subjects completed the testing around and for an actual competition event. This became the first application of sport-specific performance-related weight cutting research to the ongoing real-life phenomenon.

The knowledge gained could be useful in providing insight into the real-life phenomenon as it is occurring, guiding future weight loss plans, changing the approach to rapid weight loss, changing athlete's attitudes towards weight cutting, and possibly even leading to rule changes that prevent the "need" for dangerous procedures as was done in the National Collegiate Athletic Association wrestling program (Davis et al., 2002; Oppliger, Utter, Scott, Dick, & Klossner, 2006; Schnirring, 1998; Utter, 2001).

Hypothesis

A self-selected weight cutting regimen of 5% body weight will negatively affect the chosen parameters of striking performance (i.e., the reaction would be slowed; the explosive power generation ability, and the accuracy of punches and/or kicks, would be reduced).

Limitations

1. It was assumed that the subjects accurately recorded their weight-loss procedures and weights.
2. It was assumed that both professional and amateur mixed martial artists have a consistency within their own striking habits and technical approaches.

Delimitations

1. Due to the small nature of this athletic population, the sample was limited to 12 male subjects in Southern Alberta of varying ages and weight classes.

Chapter Summary

This chapter presented a brief overview of the phenomenon of weight cutting. The investigation was also introduced with its purpose, significance, and limitations. In the next chapter, an in-depth review of appropriate literature will be conducted.

Chapter 2: Literature Review

In this chapter, the body of literature regarding intentional dehydration for competitive purposes will be reviewed. This includes a description of the phenomenon of weight cutting, why athletic populations are using such practices, and which athletic populations are engaged in the practice. As well, I will discuss the prevalence and magnitude of the practice, how the practice is utilized, and the effect of weight cutting on a variety of physiologic, performance, and health variables. The limitations and barriers to a consensus of opinion on effect will also be presented. Martial arts striking performance is briefly summarized as a way of investigating the phenomenon of weight cutting.

Weight Cutting and Dehydration

Dehydration can be assessed in many ways, and body weight reduction is one such marker (Shirreffs, 2000). Even though weight cutting can and does involve more than just water loss, caloric restriction for example, the weight loss is primarily water weight (Timpmann et al., 2008). Therefore, a self-imposed reduction in body weight is predominately a form of dehydration that can be exacerbated by caloric restriction and/or heat exposure.

In relation to sport, exercise, and performance, dehydration can occur in two forms: exercise-induced dehydration and hypo-hydration. Exercise-induced dehydration is body weight loss during exercise brought on by sweating as a reaction to the exercise itself. Hypo-hydration in this case is the situation where athletes intentionally dehydrate themselves prior to competition or performance (Barr, 1999; Shirreffs, 2009).

Exercise-Induced Dehydration

Exercise-induced dehydration has been found to unequivocally affect performance in a negative manner (American College of Sports Medicine, American Dietetic Association, and Dietitians of Canada, 2000; Gauchard, Gangloff, Vouriot, Mallie, & Perrin, 2002; McGregor, Nicholas, Lakomy, & Williams, 1999; Sawka, Montain, & Latzka, 2001; von Duvillard, Arciero, Tietjen-Smith, & Alford, 2008; Yoshida, Takanishi, Nakai, Yorimoto, & Morimoto, 2002). The body weight reduction of approximately 2-3% through dehydration appears to be the threshold for a variety of functional decrements, including: basketball skills, tennis skills/sprinting, throwing accuracy, anaerobic strength/power, muscular power and endurance, aerobic endurance, as well as general decreases in performance capacity (Barr, 1999; Casa et al., 2000; Coyle, 2004; Devlin, Fraser, Barras, & Hawley, 2001; Dougherty, Baker, Chow, & Kenney, 2006; Jones, Cleary, Lopez, Zuri, & Lopez, 2008; Magal et al., 2003; Maughan, 2003; Montain, 2008; Murray, 2007; Rodriguez, Di Marco, & Langley, 2009; Sawka et al., 2007; Shirreffs, 2005, 2009; Walsh, Noakes, Hawley, & Dennis, 1994; "Water Deprivation and Performance of Athletes," 1974).

Hypo-Hydration

There is not a clear consensus about hypo-hydration as was found with exercise-induced dehydration, but the practice has still been found to negatively affect many aspects of performance. Hypo-hydration was found to negatively affect aerobic performance (M. Fogelholm, 1994; Sawka et al., 2001), reaction time, balance, and postural sway (American Academy of Pediatrics Committee on Sports & Fitness, 2005; Patel, Mihalik, Notebaert, Guskiewicz, & Prentice, 2007). Hypo-hydration has also been found to negatively affect general exercise performance (American Academy of Pediatrics Committee on Sports & Fitness, 2005; Caldwell, 1987; Paik et al., 2009), particularly in rowing (G. Slater et al., 2006; G. J. Slater et al., 2005; G. J. Slater et al., 2006), and more specifically in basketball, rowing, and cycling performance with a 2% body weight reduction (Baker, Dougherty, Chow, & Kenney, 2007; Burge, Carey, & Payne, 1993; Walsh et al., 1994).

Intermittent sprint time has also been found to be negatively affected (Maxwell, Gardner, & Nimmo, 1999) as well as explosive power. It should be noted that although this particular study of explosive power found that 1-2% body weight reduction affected women and not men, the researchers postulated that it would with more weight lost (Gutierrez, Mesa, Ruiz, Chirosa, & Castillo, 2003). Muscular strength and endurance have also been found to be decreased by hypo-hydration (G. M. Fogelholm, Koskinen, Laakso, Rankinen, & Ruokonen, 1993), although these decreases have been found to be far less detrimental to aerobically trained populations as compared with anaerobically trained populations at a 3% body weight reduction (Caterisano, Camaione, Murphy, & Gonino, 1988). More recently, hypo-hydration has been found to negatively impact strength, power, resistance exercise, and high-intensity exercise performance (Judelson, Maresh, Anderson, et al., 2007; Judelson, Maresh, Farrell, et al., 2007).

However, there was some contradiction about performance decrements within the literature. Aerobic performance, anaerobic performance, rowing performance, muscular strength, and endurance were found to recover with at least five hours of adequate rehydration and re-feeding (G. M. Fogelholm et al., 1993; M. Fogelholm, 1994; G. J. Slater et al., 2005). More confounding studies that detracted from a consensus included finding that hypo-hydration decreases muscular endurance but not strength (Montain et al., 1998) and that sprint or vertical jump performance were not impaired (Watson et al., 2005). Furthermore, in direct contradiction, hypo-hydration has been found to both increase oxidative stress and DNA damage (Paik et al., 2009), but also to not enhance muscle damage after resistance exercise (Yamamoto et al., 2008).

Hypo-Hydration and Weight-Class Based Sports

This phenomenon of hypo-hydration or weight cutting has been explored directly from many research angles in a variety of previously mentioned weight class sports, such as wrestling, judo, boxing, tae kwon do, and MMA for example. Some of the research streams included the effect of weight cutting on long-term growth and anthropometrics, psychological measures, work capacities, metabolism, muscular strength, muscular endurance, immune function, aerobic power, anaerobic power, physiological parameters (blood metabolites for example), its relation to winning or success, and even to academic grades. The bulk of this research has involved wrestling because it has the most common and longest usage of the phenomenon. The practice received special interest after the three NCAA deaths referred to in chapter one (Hoey, 1998; Remick et al., 1998). More recently, judo is becoming more researched.

This intentional and purposeful loss of body weight to compete in a lower weight class may be achieved through a variety of active or passive methods with the primary objective of losing water weight, which involves the athlete rapidly reducing body weight for a competitive weigh in to gain a size, leverage power, and/or strength advantage (Brownell, Steen, & Wilmore, 1987; Horswill, 1992, 1993, 2009; Oopik et al., 2002; Oppliger, Case, Horswill, Landry, & Shelter, 1996; Oppliger, Steen, & Scott, 2003;

"Water Deprivation and Performance of Athletes," 1974; Wroble & Moxley, 1998b). As mentioned, weight cutting exists in weight-class-based combative sports such as wrestling, boxing, and martial arts such as judo, tae kwon do, karate, and mixed martial arts. The practice even exists in non-combative weight-based sports such as power lifting, rowing, and horse racing (Beljaeva & Oopik, 2001; Horswill, 1992; Kazemi, Shearer, & Choung, 2005; Schoffstall, Branch, Leutholtz, & Swain, 2001; M. S. Smith, Dyson, Hale, Harrison, & McManus, 2000; Waslen, McCargar, & Taunton, 1993).

Combative weight class athletes will routinely lose between 5 and 10% of their body weight to compete in lower classes (American College of Sports Medicine, 1976; Artioli et al., 2010; Brownell et al., 1987; Hall & Lane, 2001; Horswill, 1993; Kiningham & Gorenflo, 2001; Ribisl, 1975; M. S. Smith et al., 2000; Steen & Brownell, 1990). This weight loss is achieved through a variety of potential methods, including increased exercise, decreased caloric intake/ energy restriction, fluid restriction, heat exposure (e.g., sauna/steam), exercising in heat exposure, diuretics, laxatives, and even vomiting (Clarkson, Manore, Oppliger, Steen, & Walberg-Rankin, 1998; Horswill, 1992, 1993; Kiningham & Gorenflo, 2001; Oppliger et al., 2003; Wroble & Moxley, 1998b).

Weight cutting can be very frequent, based on competitive needs. Essentially, the prevalence of weight cutting will parallel the frequency of competition. The practice has been described in wrestlers as occurring approximately 10 to 15 times per season with a range of 2.0 to 2.9 kilograms lost on a weekly basis (Oppliger et al., 1996; Oppliger, Landry, Foster, & Lambrecht, 1993; Oppliger, Landry, Foster, & Lambrecht, 1998; Oppliger et al., 2003). Judokas were found to have reduced their weight roughly two to five times a year, although many reduced their weight six to 10 times a year and were found to have started the practice generally before 15 years old (Artioli et al., 2010).

The percentage of wrestlers who practice weight cutting has varied in research, but with a range of 32% to 89%, the phenomenon is real and a part of weight class sports (Artioli et al., 2010; Horswill, 1993; Kiningham & Gorenflo, 2001; Lakin, Steen, & Oppliger, 1990; Oppliger et al., 1998; Steen & Brownell, 1990). Most recently, 82% of judokas were found to engage in the practice (Artioli et al., 2010). Weight cutting is also prevalent in boxing, tae kwon do, and general combative sports or mixed martial arts (Hall & Lane, 2001; Kiningham & Gorenflo, 2001; M. Smith et al., 2001; M. S. Smith et al., 2000).

The Consequences of Weight Cutting

Weight cutting has been found to have little or no effect on anthropometrical or long-term growth in judokas (Waslen et al., 1993) and wrestlers (Housh et al., 1997; Housh, Johnson, Stout, & Housh, 1993; Nelson, 1962; Nitzke, Voichick, & Olson, 1992; Roemmich & Sinning, 1997; Singer & Weiss, 1968). Although it should be noted that weight cutting has been linked to long-term weight development in boxers, wrestlers, and weight lifters and that the practice may enhance weight gain or predispose to obesity in later life (Saarni, Rissanen, Sarna, Koskenvuo, & Kaprio, 2006).

Weight cutting has been investigated in relation to success or winning in wrestlers and found to have a mixed effect. Utter and Kang (1998) were the only researchers who found no affect, while weight cutting was found to have a positive correlation to success in two other studies (Wroble & Moxley, 1998a, 1998b). While weight cutting may have contributed to winning, it had no effect on academic grades of wrestlers (Burcham, Gerald, Hunt, & Pope, 2006).

There have been mixed results regarding the effect of weight cutting on metabolism. While there was no effect found in judokas (Waslen et al., 1993) and for the most part in wrestlers (McCargar & Crawford, 1992; Melby, Schmidt, & Corrigan, 1990; Schmidt, Corrigan, & Melby, 1993), weight cutting has been found to slightly decrease resting energy expenditure (Oopik et al., 1996; Steen, Oppliger, & Brownell, 1988).

In other research, weight cutting has been found to consistently have a negative effect on psychological and cognitive function in judokas (Degoutte et al., 2006; Filaire, Maso, Degoutte, Jouanel, & Lac, 2001; Koral & Dosseville, 2009; Yoshioka et al., 2006) and in wrestlers (Choma, Sforzo, & Keller, 1998; Landry, 1998). It should be noted that Landry (1998) found a decrease in psychological variables, but no change in cognitive function.

Another stream of research with a consensus was that of various indices of immune function. While it has not been well researched in wrestlers, with only one study (Whiting, Gregor, & Finerman, 1988) finding a negative impact, this damaging effect has been well documented in judokas (Finaud et al., 2006; Kowatari et al., 2001; Ohta et al., 2002; Suzuki et al., 2003; Umeda, Nakaji, Shimoyama, Kojima, et al., 2004; Yaegaki et al., 2007). A similar health-related stream of research that only appeared in studies related to judokas is that of bone health. Unlike previous areas, results were mixed. Some of the research documented the negative effect of weight cutting on bone health markers, contrasted with no effect in light of mediation from heavy training (Prouteau, Benhamou, & Courteix, 2006; Prouteau, Pelle, Collomp, Benhamou, & Courteix, 2006).

Yet another stream of research in uniform agreement was that of physiological blood and substrate parameters. There was an undisputed negative effect in judo (Degoutte et al., 2006; Filaire et al., 2001; Prouteau, Benhamou, & Courteix, 2006) as well as in wrestling (Hickner et al., 1991; Horswill, Park, & Roemmich, 1990; Karila et al., 2008; Strauss, Lanese, & Malarkey, 1985; Tarnopolsky et al., 1996; Webster, Rutt, & Weltman, 1990).

Weight cutting has also been investigated in relation to performance measures. The phenomenon has been found to have a unanimous negative effect on judo performance (Degoutte et al., 2006; Filaire et al., 2001; Koral & Dosseville, 2009; Prouteau, Ducher, Serbescu, Benhamou, & Courteix, 2007). It has been found to negatively impact anaerobic output in both wrestlers and judokas (Maffulli, 1992; Umeda, Nakaji, Shimoyama, Yamamoto, et al., 2004; Webster et al., 1990). There is also an overwhelming negative impact found in relation to physical work capacity in wrestling (Herbert & Ribisl, 1972; Hickner et al., 1991; Horswill, Hickner, Scott, Costill, & Gould, 1990; Klinzing & Karpowicz, 1986; Maffulli, 1992; Oopik et al., 1996; Oopik et al., 2002; Rankin, Ocel, & Craft, 1996; Ribisl & Herbert, 1970). However, some studies have found working capacity to not be affected (Kraemer et al., 2001; McMurray, Proctor, & Wilson, 1991), or even improve with weight cutting (G. M. Fogelholm et al., 1993).

In relation to strength, the effect of weight cutting is uncertain. Both a negative influence and mixed results have been found in relation to wrestlers (Maffulli, 1992; Webster et al., 1990). Strength has also been investigated in power lifters, and it was found that weight cutting negated strength (Schoffstall et al., 2001).

Full-Contact Forms of Martial Arts

The problem with this volume of research is that it comes from non-contact, non-striking forms of martial arts or sports as opposed to full-contact striking martial arts and mixed martial arts. Some studies have been performed with mixed populations of both contact and non-contact weight cyclers. Jauhiainen, Laitinen, Penttilä, Nousiainen, and Ahonen (1985) investigated the effect of a 5% weight cut by varying methods (e.g., sauna, diuretic, exercise, control) on blood physiology alterations in wrestlers, judokas, boxers, and weight lifters. The researchers found that blood lipids and proteins increased with sauna and diuretic dehydration, but not with exercise. This was most likely related to the moderating effects from increased heavy training. An important note is that different methods of weight loss cause different physiological alterations and that the levels of aerobic and anaerobic training can also create variation. Roots, Timpmann, and Oopik (2000) examined the role of weight cutting on the physiologic blood lipid profile and found no adverse effect of the practice in karatekas, wrestlers, boxers, and judokas. Timpmann et al. (2008) investigated the effect of a 5% weight cut on work, strength, metabolites, and urea in wrestlers and karatekas. A key principle is that this study was one of the first studies to focus on a "self-selected regimen" of weight loss rather than one imposed by the researcher. It was concluded that weight cutting decreased work and strength while increasing metabolites and urea (Jauhiainen et al., 1985; Roots et al., 2000; Timpmann et al., 2008).

An even smaller field of research has been conducted exclusively on full-contact striking combative sports. This included research into karate, boxing, tae kwon do, general combative sports, and/or mixed martial arts.

In karate, a 5% weight reduction over five days decreased physical working capacity, which was not maintained by creatine supplementation. However, creatine appeared to maintain peak force and angular velocities as opposed to the decrease observed in placebo trials (Oopik et al., 2002).

A 6% weight cut in tae kwon do practitioners was found to decrease exercise time, peak blood lactate, maximal running time, heart rate, and muscular endurance. While muscular endurance decreased, strength and power remained. Likewise, while maximal running time and heart rate decreased, maximal oxygen uptake did not change (Lee, 1997). Also, a 5% reduction was associated with a decrease of anaerobic high-intensity performance in lightweight athletes as compared to heavyweights (Kijin & Wookwang, 2004).

Although simulated sports performance has become more and more popular in research related to weight cutting, this has not been fully realized in other sports as compared with boxing. It was found that a loss of body mass diminished simulated boxing performance; however, some athletes appeared predisposed to better handle dehydration and not demonstrate performance decrements (M. S. Smith et al., 2000). In a similar boxing performance task, a negative effect was found overall, but with a few outliers who saw no decrement or even improvement (M. Smith et al., 2001). Lastly, weight cutting was found to negatively impact mood and simulated performance (Hall & Lane, 2001). Essentially, all three found performance decreases due to weight cutting.

Only one study to date has investigated weight cutting in general combative sporting athletes. They were not designated mixed martial artists, but they were not designated into other sports either. Timpmann, Oopik, Paasuke, Medijainen, and Ereline

(2004) examined the effect of a 5% weight cut on strength, work, and blood metabolites in this undefined population of general combative athletes. It was concluded that there was an increase in metabolites as well as urea from protein degradation. Also, work and strength were impaired in a 3-minute variable intensity exercise, attempting to replicate the high intensity and aerobic demands of combative sports (Timpmann et al., 2004).

Barriers to Consensus on the Effects of Weight Cutting

Unfortunately, there were barriers to a consensus on the effects of weight cutting. These barriers included the methods used in varying research, researcher imposed protocols, and differing rehydration times. Timpmann et al. (2008) suggested that the main problem was researcher-imposed weight controls and, as such, were the only researchers to use a self-selected weight-loss protocol. Results from previous studies may have been confounded by the fact that the subjects were not allowed to use their own developed and practiced procedure of weight loss. Instead, according to Timpmann et al. (2008), subjects were to use prescribed methods they may not have preferred nor had experience with. Another conflicting issue was the differing tests and measures of performance; as well, these tests were not necessarily being sport specific. While one test might accurately represent one sport, the results and trends may not transfer to a different sport. The last major problem was differing rehydration times between weigh in and competition between sports. Only mixed martial arts of the striking contact sports have the large window of 24 hours. All other sports have resorted to shorter rehydration times; therefore, again, results and trends are not applicable to other timelines from other sports. Large timelines have been used for wrestling, but not the full 24 hours of rehydration as is found in mixed martial arts.

Anaerobic power and strength have been vastly studied with mixed results in relation to weight cutting because they have been described as the key to success in wrestling (Horswill, 1992). However, anaerobic power and strength have not been investigated relative to martial arts striking performance and parameters.

Dehydration has been associated with negative effects on reaction time and accuracy. Reaction time has been described as negatively affected by dehydration, but this link has not been established directly to hypo-hydration (American Academy of Pediatrics Committee on Sports & Fitness, 2005). These parameters have not only been ignored for the most part in hypo-hydration, they are also absent from research relating to full contact combative striking sports. The effect of weight cutting on strike accuracy has yet to be investigated in contact combative weight class sports such as mixed martial arts, even though accuracy has been found to decrease in relation to exercise induced dehydration (Devlin et al., 2001). Essentially, factors such as reaction time and accuracy have not been fully investigated in relation to hypo-hydration for making weight.

Martial Arts Striking Performance

Power, speed, and timing are some of the most important factors for martial arts striking performance. Power can be thought of as explosive force (i.e., the product of force and speed) or an athlete exerting their strength quickly. Speed and timing include both muscular speed and reaction time. Aspects of the fundamental parameters of power, speed, and timing have been investigated through a wide variety of indirect and direct methods. This body of literature has been summarized, including the existing limitations (Chang, Evans, Crowe, Zhang, & Shan, 2011). It should be noted that none of this summarized literature on martial arts striking performance investigated the phenomenon of weight cutting in any way.

Chapter Summary

Dehydration negatively effects athletic performance, but the effect of self-induced weight cutting with a subsequent rehydration period remains less clear. There were large gaps across the literature and many barriers to a consensus on the effect of the phenomenon. There was minimal research on weight cutting in general within mixed martial artists as an athletic population, and only one study utilizing non researcher imposed weight loss methods. Also, researchers have yet to utilize a sport-specific performance test for mixed martial arts, with either common strikes, strike parameters, or high-intensity intermittent exercise of five minutes representing one round of mixed martial arts competition.

Weight cutting has been investigated from a variety of approaches in a variety of weight-class-based sports; to date, no research has utilized a full-body, three-dimensional motion capture system to quantify changes in striking mechanics and parameters in relation to weight cutting. These striking parameters include velocities and accelerations, which can be equated to strike power or force, reaction time, and accuracy.

Chapter 3: Methodology

My aim in this chapter is to present the materials and methods used to investigate the effect of weight cutting on martial arts striking parameters. This includes the laboratory set up of a synchronized motion capture system, electromyography unit, and an optical trigger device. As well, I present an explanation of the quantification of power, reaction time, and accuracy based on strike timing, 3D kinematic characteristics of the punching bag and striking limbs, electromyography measurement, and the optical trigger signal. Lastly, a description of the application of the quantifying methods to a pre- and post-test design investigating weight cutting, the characteristics of the subjects tested, and the statistical analysis will be presented.

3D Motion Capture and Laboratory Set-Up

Once ethical approval was received from the University of Lethbridge (see Appendix A), the laboratory was set up with a 12-camera VICON 3D motion capture system that was used to quantitatively determine the whole body kinematic characteristics during each striking movement. VICON software (www.vicon.com) was configured to capture movement at a rate of 200 frames per second. Calibration residuals were determined in accordance with VICON's guidelines and yielded positional data accurate within 1 mm.

Each subject was fixed with 39 reflective markers with a diameter of 9 mm. The markers reflected infrared light emitted from the cameras and their positional data were recorded by said cameras. These markers were placed at specific bony and body landmarks to create 15 segments and a full body biomechanical model using previously existing methods (Shan, Bohn, Sust, & Nicol, 2004; Shan & Westerhoff, 2005; see also Figure 1).

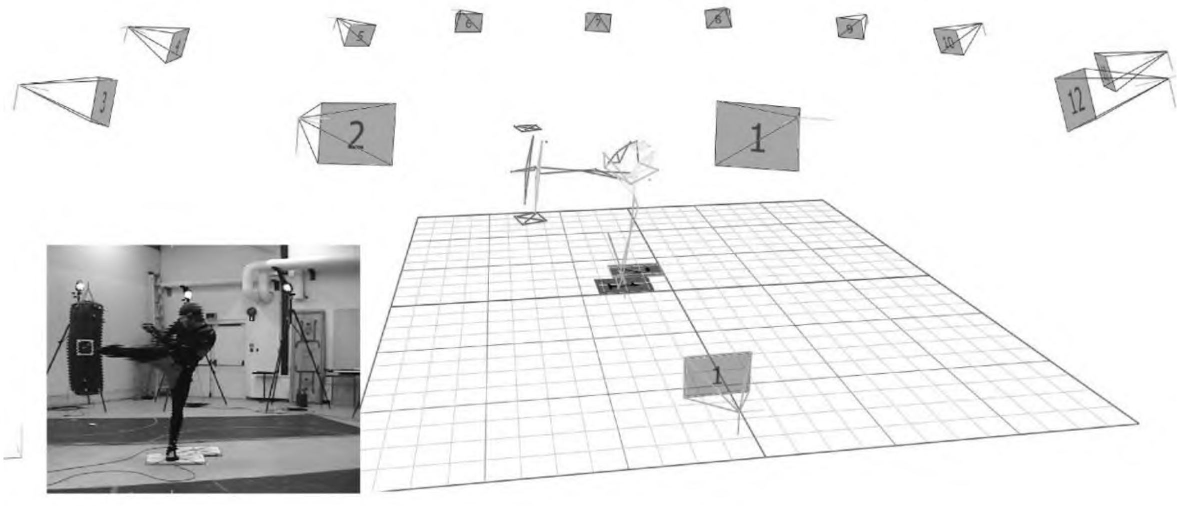

Figure 1. The set-up of synchronized 3D data collection.[1]

The segments consisted of the head and neck, upper trunk, lower trunk, two upper arms, two lower arms, two hands, two thighs, two shanks, and two feet. To create the head segment, markers were placed on the left and right temples and two on the posterior portion of the parietal bone. The upper trunk and arm segments were created by markers on the sternal notch, xiphoid process, C7 and T10 vertebrae, right back, left and right acromion processes, left and right lateral epicondyles of the humerous, styloid processes of the ulna and radius, right and left third metacarpophalangeal joints, as well as the right and left upper and lower arms. The lower torso/pelvis and leg segments were created

[1] From "An Innovative Approach for Real Time Determination of Power And Reaction Time in A Martial Arts Quasi-Training Environment Using 3D Motion Capture and EMG Measurements," by S.-T. Chang, J. Evans, S. Crowe, X. Zhang, & G. B. Shan, 2011, *Archives of Budo, 7*, p. 187. Copyright 2011 by Chang et al. Reproduced with permission.

from markers placed on both the right and left following landmarks: the anterior superior iliac crest, posterior superior iliac crest, lateral condyle of the tibia, lateral malleolus of the fibula, calcaneal tuberosity, head of hallucis, upper leg/thigh, and tibia. The raw kinematic data were processed using a five-point smoothing filter (1-3-4-3-1 function).

In addition, a standard punching bag was outfitted with 15 markers. Four were located on the top and four on the bottom to provide a frame for the bag. Another seven markers were used as targets, with three vertical left markers, three vertical right markers, and one front marker whose height matched the highest side markers. The frame markers were used to determine the striking power of the athlete. The target markers corresponded to the body targets of the most common strikes: left jab (left straight punch) and right straight punch to the head, hooks to the head and body, as well as left and right kicks to the head, body, or legs. These target markers, combined with the carefully placed striking markers on the middle knuckle of the glove and lower shin, allowed for an investigation of accuracy. The shin marker was placed at the lower third of the shank and then adjusted based on the subjects' preferred contact area. The height of the bag was standardized by hanging it so that the subject's lowest lateral rib matched the height of the middle or body targets. The high/head and low/leg targets were placed at 20% of body height away from midpoint marker, which was already located at the middle of the bag.

Kinematic data of the subject and bag were calculated based on the data collected from the 3D motion capture system using previously mentioned methods. This data included positional changes, velocities, and accelerations.

The optical signal system of three LED lights was synchronized to the system and controlled by the researcher. These signal lights were used to initiate the time of strike as well as to indicate to the subject the location of (or style of) strike. The lights were placed at the top of the bag at eye level without interfering with the targets. This allowed for random selection of the strike within the chosen style and when combined with electromyography (EMG) and motion data allowed for a thorough investigation of reaction time.

Power Quantifications[2]

Power and force were mathematically determined from the kinematic data using the method proposed by Chang et al. (2011). This method was specifically developed for this research project. Using this method, the movement of the punching bag was used to determine the power in the strike. Treating the punching bag as a rigid body and utilizing the related coordinate data, linear and angular power were able to be calculated and, hence, the total power as well.

$$P_T = P_L + P_A \qquad [1]$$

Where P_T is the total power, P_L and P_A are the linear and angular powers respectively.

Linear power calculations. In order to determine linear power, the velocity of the centre of the bag ($\vec{v}$) and the force applied to the bag ($\vec{F}$) needed to be quantified. The eight frame markers of the punching bag provided this information. Since the cylindrical punching bag had a uniform density and was symmetric in both vertical and horizontal directions respectively, the centre of mass was determined with coordinates *x, y*, and *z*, in their respective planes.

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[2] The approach and equations used in this presentation follow the collaborative research I completed as reported in "An Innovative Approach for Real Time Determination of Power And Reaction Time in A Martial Arts Quasi-Training Environment Using 3D Motion Capture and EMG Measurements," by S.-T. Chang, J. Evans, S. Crowe, X. Zhang, & G. B. Shan, 2011, *Archives of Budo, 7*(3), 185-196. Copyright 2011 by Chang et al.

Using the coordinate data, vectors were produced representing the movement/ position, velocity (first derivative of *Equation 2*), and acceleration (second derivative of *Equation 2*) of the rigid body for each frame.

$$\begin{cases} v_1 = \dot{x} \\ v_2 = \dot{y} \\ v_3 = \dot{z} \end{cases} \qquad [2]$$

For *Equation 2*, $\bar{v}$ is the velocity vector of the centre of the punching bag, and v_1, v_2, and v_3 are the velocities of the bag in their respective *x*, *y*, and *z* directions. Each velocity was determined by the first derivatives: $\dot{x}$, $\dot{y}$ and $\dot{z}$, in their respective *x*, *y*, and *z* directions.

Basic physics calculations were used to determine the linear force ($\bar{F}$) exerted on the bag (Newton's 2nd Law, *Equation 3*) and using physics theory, the linear power was able to be determined.

$$\begin{cases} F_1 = m\dot{v}_1 \\ F_2 = m\dot{v}_2 \\ F_3 = m\dot{v}_3 \end{cases} \qquad [3]$$

For *Equation 3*, $\bar{F}$ is the force vector applied to the punching bag, m is the mass of the punching bag, and $\dot{v}_1$, $\dot{v}_2$, and $\dot{v}_3$ are the accelerations in their respective *x*, *y*, and *z* directions (or first derivatives of the previously obtained velocities). Accelerations as stated were the derivative of velocities or the second derivative of the positional data.

Using *Equation 3*, F_1, F_2, and F_3 were calculated: that is, the applied force in the *x*, *y*, and *z* directions respectively. Therefore, the linear power equation was as follows:

$$P_L = \vec{F} \cdot \vec{v} = F_1 v_1 + F_2 v_2 + F_3 v_3 \qquad [4]$$

A program written in MATLAB was used to help determine the linear power.

Angular power calculations. To determine angular power, the rotational characteristics of the bag movement during and after contact were of import. Again, using the coordinate data, positional vectors were determined for each frame. Based on engineering physics (Meriam & Kraige, 2008), the rotational characteristics and angular power were calculated using the Euler Angle System and angular dynamics. The marked bag and principles of Euler angles are presented in Figure 2.

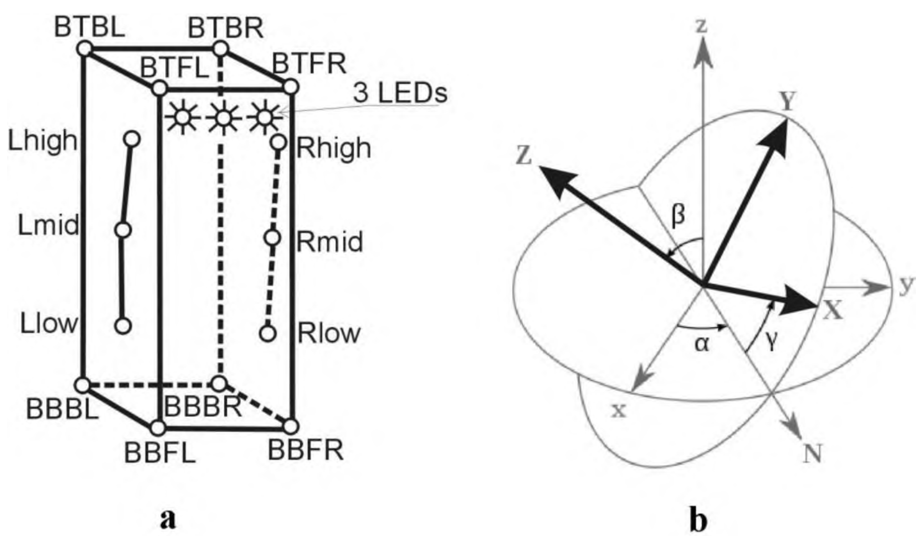

Figure 2. Punching bag set-up (2a) and Euler angle principles (2b) used to represent the angular rotation of the punching bag.[3]

[3] From "An Innovative Approach for Real Time Determination of Power And Reaction Time in A Martial Arts Quasi-Training Environment Using 3D Motion Capture and EMG Measurements," by S.-T. Chang, J. Evans, S. Crowe, X. Zhang, & G. B. Shan, 2011, *Archives of Budo, 7*(3), p. 189. Copyright 2011 by Chang et al. Reproduced with permission.

The explanation of the bag marker set in Figure 2a is as follows: BTBL = bag top back left, BTFL = bag top front left, BTBR = bag top back right, BTFR = bag top front right, BBBL = bag bottom back left, BBFL = bag bottom front left, BBBR = bag bottom back right, and BBFR = bag bottom front right represent the markers on the eight corners of the bag. Markers were also placed on the sides to provide a target for the participant; Lhigh, Lmid, and Llow, Rhigh, Rmid, and Rlow. The front marker matches the height of the Rhigh and Lhigh markers and is not included in the figure due to overcrowding with the signal lights.

The principles of Euler angles used to represent the angular rotation of the punching bag are depicted in Figure 2b. Lower case letters *x, y,* and *z* represent the initial axis of an object, and capital letters *X, Y* and *Z* represent the axes after rotation. *N* represents a common line between the position before and after rotation (an intersection of the *xy* and the *XY* planes). The Euler angles α, β, and γ represent the angle between the *x*-axis and *N*, the angle between the *z*-axis and the *Z*-axis, and the angle between *N* and the *X*-axis respectively.

Any three consecutive rotations of a rigid body can be represented with Euler angles (α, β, and γ). Based on previous methods (Trucco & Verri, 1998), an angle between two consecutive vectors needed to be calculated in order to determine Euler angles: that is, the time change of a selected vector. The specific vector chosen was from the centre of the bag to the bag top back right marker (BTBR). As stated, positional vectors were calculated for each frame from the coordinate data. These positional vectors build a rotational matrix by Euler's theorem, which states that any 3D rotation can be represented by a rotation around a unit vector $\vec{n} = [n_1, \ n_2, \ n_3]^T$. The value for $\vec{n}$ can be determined using the dot product of the vector positions. The angles between vectors were expressed using θ, which, again, were determined from the coordinate data. Once $\vec{n}$ was determined, the rotation matrix (R) was expressed as follows:

$$R = I\cos\theta + (1-\cos\theta)\begin{bmatrix} n_1^2 & n_1n_2 & n_1n_3 \\ n_2n_1 & n_2^2 & n_2n_3 \\ n_3n_1 & n_3n_2 & n_3^2 \end{bmatrix} + \sin\theta\begin{bmatrix} 0 & -n_3 & n_2 \\ n_3 & 0 & -n_1 \\ -n_2 & n_1 & 0 \end{bmatrix} \quad [5]$$

where I is identity matrix, i.e. $\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$

On the other hand, when the rotation matrix R is expressed using Euler Angles (α, β, and γ), it has the following form:

$$R = \begin{bmatrix} \cos\beta\cos\gamma & -\cos\beta\sin\gamma & \sin\beta \\ \sin\alpha\sin\beta\cos\gamma & -\sin\alpha\sin\beta\sin\gamma+\cos\alpha\cos\gamma & -\sin\alpha\cos\beta \\ -\cos\alpha\sin\beta\cos\gamma+\sin\alpha\sin\gamma & \cos\alpha\sin\beta\sin\gamma+\sin\alpha\cos\gamma & \cos\alpha\cos\gamma \end{bmatrix} \quad [6]$$

From *Equation 5* and *Equation 6*, α, β, and γ were determined, and after these Euler angles were obtained, the angular velocity of the bag was calculated based on *Equation 7* (Meriam & Kraige, 2008).

$$\begin{cases} \omega_1 = \dot{\alpha}\sin\beta\sin\gamma + \dot{\beta}\cos\gamma \\ \omega_2 = \dot{\alpha}\sin\beta\cos\gamma - \dot{\beta}\sin\gamma \\ \omega_3 = \dot{\alpha}\cos\beta + \dot{\gamma} \end{cases} \quad [7]$$

For *Equation 7*, ω_1 represents the angular velocity on the *x*-axis, obtained from the first derivative of the related Euler angles. Similarly, ω_2 and ω_3 represent the angular velocity on the *y* and *z*-axis respectively.

In order to calculate the angular power, the moment of inertia of the bag needed to be determined. Again, treating the punching bag as a rigid body with a cylindrical shape allowed the quantification of its moment of inertia.

$$\begin{cases} I_1 = I_2 = \frac{1}{12}m(3r^2 + h^2) \\ I_3 = \frac{1}{2}mr^2 \end{cases} \quad [8]$$

For *Equation 8*, ***m*** is the mass of the punching bag, ***r*** is radium of the bag, ***h*** is the height of the bag, I_1, I_2, and I_3 are the moment of inertia in the medial-lateral, anterior-posterior, and vertical directions respectively. Because of the symmetry of the punching bag, they are equal to each other. After the determination of angular velocities (*Equation 7*) and the moments of inertia (*Equation 8*), the moment $\overrightarrow{M}$ (torque) applied to the bag could be calculated using Euler equations (*Equation 9*):

$$\begin{cases} M_1 = I_1\dot{\omega}_1 + (I_3 - I_2)\omega_2\omega_3 \\ M_2 = I_2\dot{\omega}_2 + (I_1 - I_3)\omega_3\omega_1 \\ M_3 = I_3\dot{\omega}_3 + (I_2 - I_1)\omega_1\omega_2 \end{cases} \quad [9]$$

For *Equation 9*, M_1, M_2, and M_3 represent the components of moment (or torque) in the *x*, *y*, and *z*-axis respectively. I_1, I_2, and I_3 are the moments of inertia and ω_1, ω_2, and ω_3 represent the angular velocities as previously calculated. The angular accelerations of $\dot{\omega}_1$, $\dot{\omega}_2$, and $\dot{\omega}_3$ in the respective *x*, *y*, and *z*-axis were obtained by taking the first derivative of ω_1, ω_2, and ω_3.

Finally, angular power (P_A) was calculated by multiplying these three torques (M_1, M_2, and M_3) by the corresponding angular acceleration values ($\omega_1, \omega_2, \omega_3$) to find the magnitude of those vectors (see *Equation 10*).

$$P_A = \vec{M} \cdot \vec{\omega} = M_1\omega_1 + M_2\omega_2 + M_3\omega_3 \qquad [10]$$

An example of the quantified components of power is presented in Figure 3.

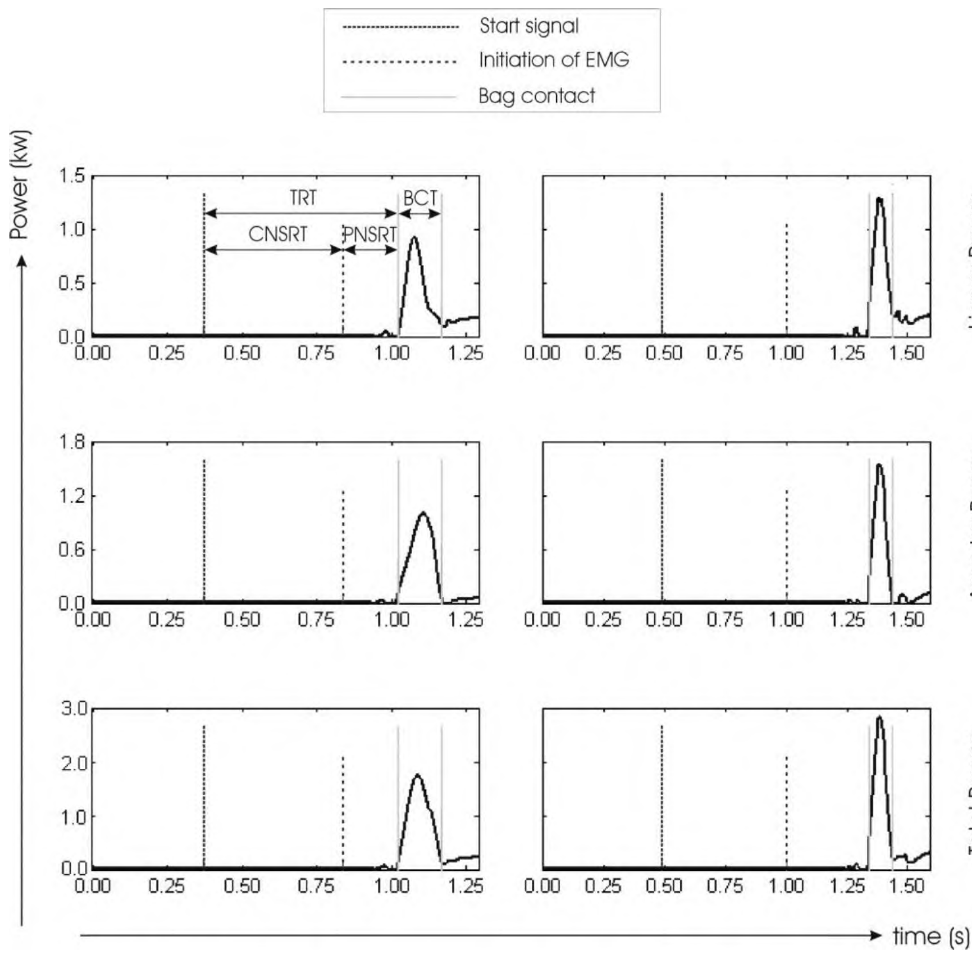

Figure 3. Typical power generation of a 185 lb athlete during a left straight punch (right column) and a left hook (left column). As shown in the data presented in this figure, a hook generated higher maximal power than a straight one.[4]

[4] From "An Innovative Approach for Real Time Determination of Power And Reaction Time in A Martial Arts Quasi-Training Environment Using 3D Motion Capture and EMG Measurements," by S.-T. Chang, J. Evans, S. Crowe, X. Zhang, & G. B. Shan, *Archives of Budo, 7*(3), p. 191. Copyright 2011 by Chang et al. Reproduced with permission.

EMG Measurement and Reaction Time Calculations

Similarly to power and force, reaction time was determined using the method proposed by Chang et al. (2011). As previously stated, this method was specifically developed for this research project. An eight-channel, wireless NORAXON (www.noraxon.com) surface EMG with a gain of 1,000 was used to determine selected muscle activity. NORAXON's hardware specifications provided raw signal recordings at a rate of 1,000 Hz with a band pass filter of 16-500 Hz. This EMG unit was synchronized with the motion capture system, and this set-up allowed for an investigation of muscular recruitment, activation, and onset differences. Muscles investigated included the right and left biceps brachii, triceps brachii, vastus medialis, and biceps femoris.

The LED optical signal system was used to indicate to the subject to start the appropriate strike. The signals were used for the breakdown of left and right hand strikes, including straights to the head, hooks to the head, and hooks to the body. It also indicated the appropriate height of a kicking strike to the head, body, or legs. This investigative set-up of synchronized 3D motion capture, EMG, and optical trigger system allowed for an assessment and breakdown of reaction time. The breakdown of reaction time consisted of two periods: (a) central nervous system (CNS) response time and (b) peripheral nervous system (PNS) response time. Quantification of participants' reaction time is presented in Figure 4.

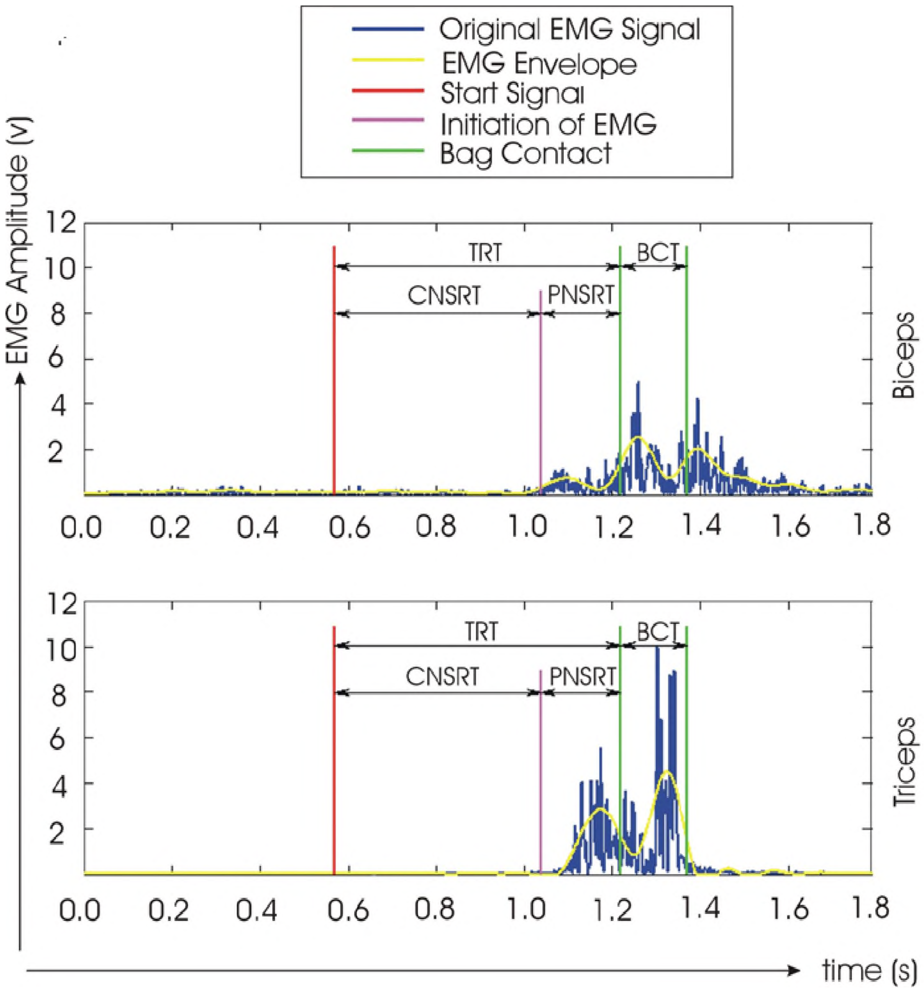

Figure 4. Quantification of reaction time using our synchronized device and EMG enveloping method.[5]

The CNS response time was determined by the time elapsed from the start of the stimulus (light signal onset) until the initiation of the PNS response (measured via EMG). The initial muscle activation or onset of the PNS response was determined using existing methods (Basmajian & De Luca, 1985): (a) obtain an EMG envelope using the Butterworth filter; (b) calculate the mean and standard deviation values between the start of the motion capture to the onset light signal (where there is minimal muscular activity);

[5] From "An Innovative Approach for Real Time Determination of Power And Reaction Time in A Martial Arts Quasi-Training Environment Using 3D Motion Capture and EMG Measurements," by S.-T. Chang, J. Evans, S. Crowe, X. Zhang, & G. B. Shan, 2011, *Archives of Budo, 7*(3), p. 192. Copyright 2011 by Chang et al. Reproduced with permission.

and (c) assign the initiation of the PNS to the point where the EMG value exceeds $\mu + 1.3\sigma$ between the onset light signal until the maximum envelope value.

The PNS response time was measured from this calculated point of muscle initiation until the point of initial contact of the striking limb with the punching bag, which was obtained from the coordinate data. The sum of these two aspects (i.e., CNS and PNS responses) provided an overall reaction time to the given stimulus.

Accuracy Calculations

Accuracy was determined by quantifying the minimum distance between the appropriate target and strike marker using the *Equation 11*:

$$d = \sqrt{[(x_t - x_s)^2 + (y_t - y_s)^2 + (z_t - z_s)^2]} \qquad [11]$$

In using *Equation 11*, the positional coordinate data of the selected striking marker was subtracted from the positional data of the proper target marker in each of the *x, y*, and *z* directions. The individual *x, y*, and *z* component differences were squared and then summed. The square root was then taken of this sum. This standard distance formula was applied to every frame, and the minimum value was selected as the point of accuracy.

Pre- and Post-Test Design

This method of quantifying power, reaction time, and accuracy was applied to a pre- and post-test design to investigate the effect of a self-selected weight cut regiment on these parameters. As previously mentioned, a variety of strikes were used for a single test: right and left straights to the head, right and left hooks to the head, right and left hooks to the body, and right and left round-house kicks to the head, body, and legs. In either test, the subject performed approximately five strikes for each selected style (i.e., five left hooks to the head and five right hooks to the head, and in the case of kicks, five left kicks to the head, five to the body, and five to the leg). These strikes were randomized by the researcher within the following categories: straights to the head, hooks to the head, hooks to the body, left kicks, and finally right kicks.

The participants came to the lab and performed a pre-test where an initial weight was recorded. Upon completion of this test, the subject was asked to reduce his body weight by 5% using self-selected methods. The participants were given one to seven days to complete the weight cut. In the cases of real competition, the subject lost the required weight to achieve their weight class and no more. Upon achieving the desired weight (i.e., 5% reduction or the necessary weight class), the subject was post-tested after a 24-hour period of rehydration and re-feeding or as close to their real competition as was feasible. Weigh in and post-test weights were also recorded as well as a loose guideline of the methods used for reducing weight.

Participant Information

Participants were trained mixed martial artists from the local Canadian Martial Arts Centre or martial artists who were interested in the study through word of mouth. I am a member of the club and have personal contact with many of the athletes. Additionally, the coach/owner of the club helped with recruitment. Recruitment was not limited to this one club as all combat athletes were welcome. Experience and age were not exclusionary factors in this research and participants' inclusion was based on the availability of the athletes. However, participation was limited to males to avoid potentially confounding factors from sex differences.

While 12 participants were tested, only seven subjects' data were used. This was due to analysis issues, time constraints, and the quality of data collection. When errors were discovered, testing could not be redone because of weight cutting and competition timing. These participants were recruited from local mixed martial arts gyms, and each participant signed a consent form prior to commencing research (see Appendix B). The pertinent information is presented in Table 1, and their weight changes during individualized weight-cut process are presented in Figure 5.

Table 1. *Participant Information*

	pre weight (kg)	weigh in (kg)	post weight (kg)	height (cm)	age (years)	years training	years professional
range	65.6 - 96.1	64 - 91.3	66.4 - 95.4	171 - 188.5	20 - 32	1.5 - 9	0 - 6
mean	78.76	75.25	79.41	179.21	25.71	5.07	2.93
SD	9.86	9.03	9.65	6.34	3.88	3.03	2.24

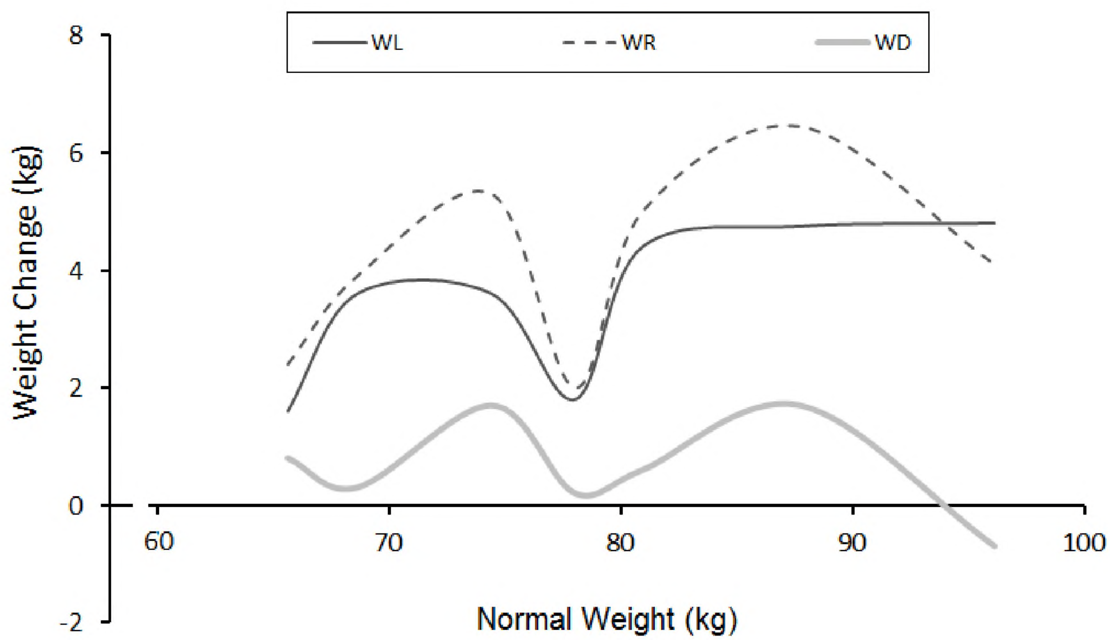

Figure 5. Weight changes during individualized weight-cut process.

Note: WL = weight loss during weight-cut process
WR = weight regain during 24-hour interval after the weigh in
WD = weight difference between the pre- and post-test

As shown in Figure 5, the data revealed: (a) Weight cutting is highly individualized, (b) Most participants compete or test at a higher body weight when compared to their pre-cut weight (i.e., WD in Figure 5), and (c) There were only a few athletes who could not regain all their lost weight or approximately return to their pre-weights (i.e., WD in Figure 5).

Statistical Analysis

Descriptive statistics such as means and standard deviations were supplied, and paired T-tests were performed on a variety of subgroups. These subgroups include the overall effect, the effect by upper or lower body strikes, the effect by individual strike style, and effect by individual participant. All statistical analysis was performed using SPSS (see Appendix C).

Chapter Summary

In conclusion, the utilized method allowed for the quantification of total power, power components (i.e., linear & angular powers), total reaction time, reaction components (i.e., central and peripheral responses), and accuracy. These parameters were tested in a pre- and post-test design to investigate the effect of cutting weight. The corresponding results of this investigation are presented in the next chapter.

Chapter 4: Results

It is my aim in this chapter to present the results of this investigation, reporting the descriptive statistics, T-test results, and the directionality of the effect. Three major parameters were presented; reaction time, power, and accuracy. Total reaction time as reported in seconds was divided into central and peripheral reactions. Total reaction time, central reaction time, and peripheral reaction time are represented by TRT, CNS, and PNS respectively. Total power as reported in Watts was separated into the maximum and average of both linear and rotational components. Power components were depicted accordingly; maximum linear power (Max LP), average linear power (Avg LP), maximum rotational power (Max RP), average rotational power (Avg RP), maximum total power (Max TP), and average total power (Avg TP). Accuracy was reported in millimeters. As described in chapter three, these results were reported for four layers of the investigation of weight cutting in a pre- and post-test design: (a) the overall effect by strike, (b) the effect isolated by upper or lower body strikes, (c) the effect by individual strike style, and (d) the effect by individual participants. All of the results demonstrating significance were labeled with an asterisk (*p*-value < 5%) and two asterisks (*P*-value < 1%). *P*-values approaching significance (< 9%) were presented to allow for discussion.

Overall Effect of Weight Cutting

A comparison of all trials for all strikes by all subjects, pre- versus post-test, is presented in Table 2. As demonstrated in Table 2, only the components of reaction time, that is total reaction (TRT), central reaction (CNS), and peripheral reaction (PNS), held significance when looking at the total effect of weight cutting. This was also highly significant for all three reaction times. It is of interest that there was a positive effect on the total and central reaction but a negative effect on the peripheral reaction. Accuracy was also approaching significance with a negative effect.

Table 2. *Results of the Overall Effect of Weight Cutting*

Metric	Test	Mean	*SD*	*P* Value	Effect
TRT	Pre	0.806	0.202	**0.000	Positive
	Post	0.755	0.185		
CNS	Pre	0.549	0.213	**0.000	Positive
	Post	0.442	0.155		
PNS	Pre	0.259	0.152	**0.003	Negative
	Post	0.314	0.128		
Max LP	Pre	664.528	524.150	0.174	Positive
	Post	1745.196	5920.441		
Avg LP	Pre	424.996	323.286	0.176	Positive
	Post	836.453	2257.936		
Max RP	Pre	2720.526	3052.292	0.285	Positive
	Post	3033.568	3613.114		
Avg RP	Pre	1789.452	2211.606	0.746	Negative
	Post	1736.275	2039.300		
Max TP	Pre	3295.677	3173.176	0.188	Positive
	Post	4704.821	8183.933		
Avg TP	Pre	2214.449	2272.025	0.404	Positive
	Post	2572.729	3409.679		
Accuracy	Pre	97.687	67.242	0.058	Negative
	Post	104.972	74.310		

Note: Results are based on collective strike total of all participants ($N = 58$)

Overall Effect by Hand and Foot Strikes

The overall effect of weight cutting as isolated to the upper body or hand strikes and to the lower body or foot strikes is presented in this section. Similar trends to the overall effect have been presented in Table 3. There was a highly significant positive effect on total and central reaction, and a negative effect on peripheral reaction.

Table 3. *Results of the Overall Effect Isolated by Hand Strikes*

Metric	**Test**	**Mean**	***SD***	***P* Value**	**Effect**
TRT	Pre	0.756	0.214	**0.000	Positive
	Post	0.702	0.189		
CNS	Pre	0.500	0.220	**0.000	Positive
	Post	0.401	0.152		
PNS	Pre	0.257	0.164	*0.035	Negative
	Post	0.301	0.117		
Max LP	Pre	485.853	401.075	0.177	Positive
	Post	2005.947	7041.772		
Avg LP	Pre	333.080	275.107	0.186	Positive
	Post	902.543	2683.092		
Max RP	Pre	2429.657	3058.301	0.378	Positive
	Post	2785.409	3613.540		
Avg RP	Pre	1659.771	2346.485	0.641	Negative
	Post	1554.745	1995.528		
Max TP	Pre	2859.830	3183.502	0.214	Positive
	Post	4743.050	9502.096		
Avg TP	Pre	1992.852	2414.467	0.444	Positive
	Post	2457.288	3843.922		
Accuracy	Pre	59.810	27.904	0.122	Negative
	Post	65.200	28.653		

Note: Results are based on collective strike total of all participants ($N = 41$).

As shown in Table 4, the overall trend was replicated again with total, central, and peripheral reaction times showing significance. This repeated the overall trend, with a highly significant positive effect on total and central reaction time. Also, matching the global trend, there was a significant negative effect on peripheral reaction time.

Table 4. *Results of the Overall Effect Isolated by Foot Strikes*

Metric	**Test**	**Mean**	***SD***	***P* Value**	**Effect**
TRT	Pre	0.928	0.089	**0.002	Positive
	Post	0.884	0.091		
CNS	Pre	0.666	0.143	**0.009	Positive
	Post	0.539	0.116		
PNS	Pre	0.262	0.122	*0.043	Negative
	Post	0.345	0.152		
Max LP	Pre	1095.474	545.386	0.479	Positive
	Post	1116.327	557.332		
Avg LP	Pre	646.677	330.543	0.147	Positive
	Post	677.061	356.321		
Max RP	Pre	3422.035	3011.194	0.407	Positive
	Post	3632.068	3651.319		
Avg RP	Pre	2102.210	1874.275	0.628	Positive
	Post	2174.084	2138.248		
Max TP	Pre	4346.838	2978.838	0.299	Positive
	Post	4612.623	3587.115		
Avg TP	Pre	2748.887	1840.252	0.506	Positive
	Post	2851.144	2088.410		
Accuracy	Pre	189.038	40.227	0.255	Negative
	Post	200.891	61.572		

Note: Results are based on collective strike total of all participants ($N = 17$).

Effect of Weight Cutting by Strike Style

Comparisons of all trials for all subjects as differentiated by strike style, pre versus post-test, are presented in the following tables. Strikes investigated include left and right hand strikes, such as hooks to the body, hooks to the head, and straights to the head. Also included are left and right foot strikes, such as round house kicks to the head, body, and legs. Presented first were left- and right-hand strikes followed by left- and right-foot strikes.

It is worth noting that left hooks to the body reiterated some of the overall trends. That is a highly significant positive effect on total reaction time and a significant positive effect on central reaction (see Table 5).

Results for left hooks to the head are presented in Table 6. There were no significant effects in any of the performance metrics.

Table 5. *Results of the Left Hooks to the Body*

Metric	Test	Mean	*SD*	*P* Value	Effect
TRT	Pre	0.836	0.258	**0.005	Positive
	Post	0.763	0.224		
CNS	Pre	0.667	0.323	*0.035	Positive
	Post	0.453	0.177		
PNS	Pre	0.167	0.194	0.102	Negative
	Post	0.309	0.071		
Max LP	Pre	560.544	377.135	0.470	Negative
	Post	525.161	412.926		
Avg LP	Pre	374.866	277.921	0.553	Negative
	Post	359.897	296.801		
Max RP	Pre	318.034	237.347	0.149	Negative
	Post	219.377	225.870		
Avg RP	Pre	176.107	145.710	0.148	Negative
	Post	126.556	145.266		
Max TP	Pre	808.593	483.843	0.120	Negative
	Post	692.747	551.097		
Avg TP	Pre	550.976	373.054	0.140	Negative
	Post	486.451	413.981		
Accuracy	Pre	46.276	22.505	0.202	Negative
	Post	60.104	34.314		

Note: Results are based on collective strike total of all participants.

Table 6. *Results of the Left Hooks to the Head*

Metric	Test	Mean	*SD*	*P* Value	Effect
TRT	Pre	0.767	0.247	0.230	Positive
	Post	0.731	0.227		
CNS	Pre	0.540	0.201	0.234	Positive
	Post	0.459	0.272		
PNS	Pre	0.230	0.142	0.487	Negative
	Post	0.276	0.097		
Max LP	Pre	370.074	337.467	0.362	Positive
	Post	4314.030	10478.447		
Avg LP	Pre	249.591	242.317	0.372	Positive
	Post	1773.937	4111.434		
Max RP	Pre	1004.639	568.985	0.405	Positive
	Post	2257.729	3473.166		
Avg RP	Pre	470.214	201.842	0.416	Positive
	Post	956.370	1350.783		
Max TP	Pre	1342.529	716.055	0.372	Positive
	Post	6547.910	13923.661		
Avg TP	Pre	719.806	414.645	0.383	Positive
	Post	2730.310	5455.911		
Accuracy	Pre	70.007	34.358	0.681	Negative
	Post	65.653	25.793		

Note: Results are based on collective strike total of all participants.

Left straight punches to the head demonstrated an approaching significant negative effect on maximum linear power (see Table 7). There was no significance found in any metric of the right hooks to the body as demonstrated in Table 8.

Table 7. *Results of the Left Straights to the Head*

Metric	Test	Mean	*SD*	*P* Value	Effect
TRT	Pre	0.650	0.244	0.259	Positive
	Post	0.599	0.156		
CNS	Pre	0.544	0.287	0.112	Positive
	Post	0.416	0.131		
PNS	Pre	0.110	0.060	0.120	Negative
	Post	0.181	0.047		
Max LP	Pre	349.044	250.766	0.057	Negative
	Post	313.649	229.737		
Avg LP	Pre	201.547	119.776	0.444	Negative
	Post	193.076	133.511		
Max RP	Pre	1081.191	470.246	0.614	Negative
	Post	1019.314	439.239		
Avg RP	Pre	655.017	290.283	0.341	Negative
	Post	580.461	249.451		
Max TP	Pre	1313.283	564.894	0.482	Negative
	Post	1235.690	547.648		
Avg TP	Pre	856.566	362.292	0.268	Negative
	Post	773.537	352.948		
Accuracy	Pre	53.459	19.909	0.175	Negative
	Post	60.450	25.495		

Note: Results are based on collective strike total of all participants.

Table 8. *Results of the Right Hooks to the Body*

Metric	**Test**	**Mean**	***SD***	***P* Value**	**Effect**
TRT	Pre	0.757	0.157	0.434	Positive
	Post	0.722	0.119		
CNS	Pre	0.405	0.128	0.443	Positive
	Post	0.360	0.072		
PNS	Pre	0.353	0.082	0.757	Negative
	Post	0.362	0.068		
Max LP	Pre	609.013	479.882	0.365	Positive
	Post	6651.842	14730.275		
Avg LP	Pre	462.477	385.689	0.365	Positive
	Post	2728.173	5464.906		
Max RP	Pre	304.828	338.262	0.335	Positive
	Post	2435.572	4796.890		
Avg RP	Pre	204.240	224.454	0.314	Positive
	Post	1045.803	1794.272		
Max TP	Pre	885.572	576.510	0.358	Positive
	Post	9046.593	19494.477		
Avg TP	Pre	666.718	449.817	0.351	Positive
	Post	3773.977	7215.257		
Accuracy	Pre	73.502	45.377	0.797	Positive
	Post	70.760	39.500		

Note: Results are based on collective strike total of all participants.

As shown in Table 9, right hooks to the head were approaching positive significance in total and central reaction time. Maximum and average linear power were also approaching significance but with a negative effect.

Table 9. *Results of the Right Hooks to the Head*

Metric	**Test**	**Mean**	***SD***	***P* Value**	**Effect**
TRT	Pre	0.820	0.196	0.070	Positive
	Post	0.756	0.223		
CNS	Pre	0.406	0.111	0.090	Positive
	Post	0.349	0.076		
PNS	Pre	0.414	0.144	0.744	Positive
	Post	0.406	0.165		
Max LP	Pre	433.897	414.034	0.089	Negative
	Post	357.444	330.166		
Avg LP	Pre	368.884	314.576	0.078	Negative
	Post	303.290	254.666		
Max RP	Pre	7479.267	2952.930	0.382	Negative
	Post	6861.971	3840.576		
Avg RP	Pre	6102.483	2173.835	0.114	Negative
	Post	4574.767	2407.993		
Max TP	Pre	7878.394	3193.736	0.329	Negative
	Post	7195.089	4059.444		
Avg TP	Pre	6471.367	2323.728	0.102	Negative
	Post	4878.054	2614.687		
Accuracy	Pre	57.280	18.466	0.802	Positive
	Post	55.669	13.513		

Note: Results are based on collective strike total of all participants.

Right straights to the head contained a significant positive effect on total and central reaction time, matching the overall trend. Accuracy demonstrated a significant negative effect (see Table 10). However, left kicks to the head or leg demonstrated no significance (see Table 11 and Table 12 respectively).

Table 10. *Results of the Right Straights to the Head*

Metric	**Test**	**Mean**	***SD***	***P* Value**	**Effect**
TRT	Pre	0.704	0.177	*0.035	Positive
	Post	0.644	0.155		
CNS	Pre	0.426	0.078	*0.031	Positive
	Post	0.364	0.093		
PNS	Pre	0.281	0.129	0.966	Positive
	Post	0.280	0.092		
Max LP	Pre	610.080	556.572	0.151	Negative
	Post	537.253	493.420		
Avg LP	Pre	359.597	286.219	0.149	Negative
	Post	317.689	251.548		
Max RP	Pre	4086.434	2404.181	0.521	Negative
	Post	3868.514	2879.987		
Avg RP	Pre	2142.634	989.002	0.313	Negative
	Post	1971.804	1072.809		
Max TP	Pre	4648.576	2936.377	0.415	Negative
	Post	4355.061	3359.091		
Avg TP	Pre	2502.234	1252.908	0.254	Negative
	Post	2289.497	1301.058		
Accuracy	Pre	60.290	21.762	*0.036	Negative
	Post	79.361	32.710		

Note: Results are based on collective strike total of all participants.

Table 11. *Results of the Left Kicks to the Head*

Metric	**Test**	**Mean**	***SD***	***P* Value**	**Effect**
TRT	Pre	0.930	0.066	0.655	Positive
	Post	0.907	0.119		
CNS	Pre	0.560	0.095	0.477	Positive
	Post	0.527	0.146		
PNS	Pre	0.370	0.035	0.742	Negative
	Post	0.377	0.064		
Max LP	Pre	1044.410	764.936	0.701	Negative
	Post	1015.207	714.658		
Avg LP	Pre	673.880	501.148	0.314	Positive
	Post	719.103	505.996		
Max RP	Pre	1619.330	400.163	0.701	Positive
	Post	1745.643	99.247		
Avg RP	Pre	1024.327	393.256	0.474	Positive
	Post	1197.120	64.829		
Max TP	Pre	2629.457	669.231	0.754	Positive
	Post	2740.813	828.164		
Avg TP	Pre	1698.210	518.588	0.441	Positive
	Post	1916.220	519.455		
Accuracy	Pre	193.143	71.483	0.606	Negative
	Post	204.610	81.591		

Note: Results are based on collective strike total of all participants.

Table 12. *Results of the Left Kicks to the Leg*

Metric	Test	Mean	*SD*	*P* Value	Effect
TRT	Pre	0.880	0.085	0.667	Positive
	Post	0.873	0.065		
CNS	Pre	0.620	0.036	0.332	Positive
	Post	0.550	0.089		
PNS	Pre	0.260	0.104	0.412	Negative
	Post	0.327	0.025		
Max LP	Pre	932.217	517.555	0.677	Negative
	Post	891.087	525.525		
Avg LP	Pre	494.120	281.656	0.409	Negative
	Post	457.423	278.717		
Max RP	Pre	1791.223	242.486	0.386	Positive
	Post	2474.060	1222.776		
Avg RP	Pre	1086.703	41.234	0.424	Positive
	Post	1480.980	648.502		
Max TP	Pre	2472.410	280.878	0.359	Positive
	Post	3189.610	1137.378		
Avg TP	Pre	1580.823	289.561	0.491	Positive
	Post	1938.400	590.122		
Accuracy	Pre	204.337	23.292	0.928	Positive
	Post	201.583	66.457		

Note: Results are based on collective strike total of all participants.

For left kicks to the body, only one metric demonstrated significance. As shown in Table 13, average rotational power had a significant negative effect.

Table 13. *Results of the Left Kicks to the Body*

Metric	**Test**	**Mean**	***SD***	***P* Value**	**Effect**
TRT	Pre	0.895	0.092	0.500	Positive
	Post	0.875	0.120		
CNS	Pre	0.440	0.226	0.540	Negative
	Post	0.515	0.106		
PNS	Pre	0.455	0.134	0.563	Positive
	Post	0.365	0.021		
Max LP	Pre	1091.815	793.084	0.388	Positive
	Post	1256.410	955.485		
Avg LP	Pre	687.435	499.380	0.328	Positive
	Post	823.095	607.949		
Max RP	Pre	686.515	145.671	0.175	Negative
	Post	550.040	91.203		
Avg RP	Pre	329.770	31.381	*0.040	Negative
	Post	277.730	26.743		
Max TP	Pre	1648.095	877.696	0.808	Positive
	Post	1667.375	965.123		
Avg TP	Pre	1017.205	467.999	0.486	Positive
	Post	1100.825	581.206		
Accuracy	Pre	143.755	8.195	0.753	Positive
	Post	122.950	63.880		

Note: Results are based on collective strike total of all participants.

For right kicks to the head, there was no significance. Total reaction time and accuracy were approaching significance with a positive effect (see Table 14).

Table 14. *Results of the Right Kicks to the Head*

Metric	**Test**	**Mean**	***SD***	***P* Value**	**Effect**
TRT	Pre	0.940	0.113	0.060	Positive
	Post	0.893	0.092		
CNS	Pre	0.760	0.050	0.274	Positive
	Post	0.597	0.144		
PNS	Pre	0.183	0.078	0.333	Negative
	Post	0.300	0.234		
Max LP	Pre	917.460	497.762	0.403	Positive
	Post	964.370	563.584		
Avg LP	Pre	600.933	355.441	0.376	Positive
	Post	648.570	413.031		
Max RP	Pre	8001.190	2582.254	0.339	Positive
	Post	8964.403	3909.428		
Avg RP	Pre	5133.327	1406.954	0.538	Positive
	Post	5522.783	2146.520		
Max TP	Pre	8740.907	2501.395	0.339	Positive
	Post	9776.523	3900.394		
Avg TP	Pre	5734.260	1227.830	0.519	Positive
	Post	6171.363	2099.429		
Accuracy	Pre	180.643	41.158	0.061	Positive
	Post	172.387	39.387		

Note: Results are based on collective strike total of all participants.

As shown in Table 15, only one performance metric demonstrated significance. There was a positive significant effect for total reaction time.

Table 15. *Results of the Right Kicks to the Leg*

Metric	**Test**	**Mean**	***SD***	***P* Value**	**Effect**
TRT	Pre Post	0.977 0.863	0.127 0.137	*0.016	Positive
CNS	Pre Post	0.780 0.543	0.072 0.139	0.191	Positive
PNS	Pre Post	0.193 0.320	0.070 0.260	0.395	Negative
Max LP	Pre Post	1226.397 1215.630	694.558 599.364	0.917	Negative
Avg LP	Pre Post	636.820 610.603	346.128 283.545	0.618	Negative
Max RP	Pre Post	5736.603 6370.953	2343.611 2412.407	0.321	Positive
Avg RP	Pre Post	3419.997 3539.383	1152.296 1190.002	0.750	Positive
Max TP	Pre Post	6752.200 7393.227	2475.285 2388.140	0.339	Positive
Avg TP	Pre Post	4056.813 4149.990	1102.730 1046.785	0.816	Positive
Accuracy	Pre Post	222.507 255.003	28.868 52.048	0.326	Negative

Note: Results are based on collective strike total of all participants.

As depicted in Table 16, many power metrics for the right kicks to the body demonstrated a significant negative effect. This included maximum and average rotational power as well as maximum and average total power. Maximum linear power was approaching significance with a positive effect.

Table 16. *Results of the Right Kicks to the Body*

Metric	Test	Mean	*SD*	*P* Value	Effect
TRT	Pre	0.937	0.099	0.118	Positive
	Post	0.890	0.106		
CNS	Pre	0.760	0.046	0.148	Positive
	Post	0.497	0.153		
PNS	Pre	0.177	0.067	0.173	Negative
	Post	0.390	0.221		
Max LP	Pre	1359.327	510.227	0.076	Positive
	Post	1401.953	530.880		
Avg LP	Pre	800.460	310.349	0.347	Positive
	Post	852.247	309.831		
Max RP	Pre	1785.507	543.187	*0.029	Negative
	Post	659.967	207.929		
Avg RP	Pre	1028.323	302.882	*0.033	Negative
	Post	394.387	109.045		
Max TP	Pre	2938.377	313.451	*0.034	Negative
	Post	1926.440	436.354		
Avg TP	Pre	1828.783	24.702	*0.047	Negative
	Post	1246.627	221.190		
Accuracy	Pre	174.750	14.613	0.154	Negative
	Post	222.830	22.913		

Note: Results are based on collective strike total of all participants..

Effect of Weight Cutting by Participant

The following tables present the effect of weight cutting by individual participants. As demonstrated in Table 17, Participant 1 had a significant positive effect on central reaction time. Total reaction time was approaching significance with a positive effect. Accuracy had a significant negative effect.

Table 17. *Results of Participant 1*

Metric	**Test**	**Mean**	***SD***	***P* Value**	**Effect**
TRT	Pre	0.530	0.085	0.054	Positive
	Post	0.463	0.061		
CNS	Pre	0.345	0.063	*0.012	Positive
	Post	0.237	0.030		
PNS	Pre	0.183	0.106	0.396	Negative
	Post	0.227	0.050		
Max LP	Pre	199.812	65.642	0.180	Positive
	Post	10901.132	16864.272		
Avg LP	Pre	145.467	55.565	0.181	Positive
	Post	4229.785	6444.609		
Max RP	Pre	1980.358	2605.883	0.254	Positive
	Post	5150.250	4972.733		
Avg RP	Pre	1866.550	3173.667	0.731	Positive
	Post	2367.378	1894.822		
Max TP	Pre	2144.227	2606.340	0.197	Positive
	Post	16024.335	21583.778		
Avg TP	Pre	2012.020	3208.973	0.289	Positive
	Post	6597.162	8037.340		
Accuracy	Pre	53.923	20.548	*0.015	Negative
	Post	79.940	30.675		

Note: Results are based on strike styles used by participant.

Participant 2 demonstrated no significance for any metric as depicted in Table 18. Central reaction time was approaching significance with a positive effect.

Table 18. *Results of Participant 2*

Metric	**Test**	**Mean**	***SD***	***P* Value**	**Effect**
TRT	Pre	0.738	0.137	0.235	Positive
	Post	0.721	0.120		
CNS	Pre	0.518	0.166	0.080	Positive
	Post	0.461	0.136		
PNS	Pre	0.220	0.151	0.234	Negative
	Post	0.260	0.091		
Max LP	Pre	379.547	160.420	0.480	Negative
	Post	364.681	180.919		
Avg LP	Pre	242.023	88.873	0.919	Positive
	Post	243.176	106.959		
Max RP	Pre	2372.250	2322.774	0.578	Negative
	Post	2196.050	2726.152		
Avg RP	Pre	1658.783	1764.360	0.288	Negative
	Post	1392.992	1688.033		
Max TP	Pre	2644.677	2309.774	0.584	Negative
	Post	2474.170	2717.905		
Avg TP	Pre	1900.809	1765.807	0.284	Negative
	Post	1636.168	1688.965		
Accuracy	Pre	131.283	75.038	0.147	Negative
	Post	144.253	85.507		

Note: Results are based on strike styles used by participant.

As shown in Table 19, Participant 3 was approaching a significant positive effect on total reaction time. Maximum linear power and average linear power were approaching significance with a negative effect.

Table 19. *Results of Participant 3*

Metric	**Test**	**Mean**	***SD***	***P* Value**	**Effect**
TRT	Pre	1.148	0.154	0.062	Positive
	Post	1.044	0.200		
CNS	Pre	0.764	0.311	0.388	Positive
	Post	0.654	0.228		
PNS	Pre	0.388	0.263	1.000	None
	Post	0.388	0.215		
Max LP	Pre	372.482	173.043	0.064	Negative
	Post	294.642	110.163		
Avg LP	Pre	251.036	108.019	0.064	Negative
	Post	209.404	88.493		
Max RP	Pre	2855.088	3081.517	0.528	Positive
	Post	3158.024	3872.602		
Avg RP	Pre	1590.866	2088.956	0.290	Positive
	Post	1888.612	2615.655		
Max TP	Pre	3168.066	3038.182	0.631	Positive
	Post	3399.382	3863.006		
Avg TP	Pre	1841.904	2090.523	0.372	Positive
	Post	2098.020	2641.990		
Accuracy	Pre	61.688	37.531	0.833	Negative
	Post	64.650	10.048		

Note: Results are based on strike styles used by participant.

Similarly, Participant 4 exhibited approaching significance for a positive effect for total reaction time. Maximum linear power and accuracy were approaching significance in a negative direction.

Table 20. *Results of Participant 4*

Metric	**Test**	**Mean**	***SD***	***P* Value**	**Effect**
TRT	Pre	0.781	0.129	0.071	Positive
	Post	0.745	0.090		
CNS	Pre	0.532	0.168	0.178	Positive
	Post	0.479	0.085		
PNS	Pre	0.250	0.111	0.578	Negative
	Post	0.265	0.083		
Max LP	Pre	1050.905	350.142	0.077	Negative
	Post	963.700	358.460		
Avg LP	Pre	637.337	183.519	0.474	Negative
	Post	610.917	185.838		
Max RP	Pre	3313.508	3572.369	0.577	Negative
	Post	3115.967	3940.590		
Avg RP	Pre	2061.255	2328.730	0.592	Negative
	Post	1943.825	2460.350		
Max TP	Pre	4206.982	3541.391	0.550	Negative
	Post	3976.999	3943.830		
Avg TP	Pre	2698.593	2321.113	0.551	Negative
	Post	2554.738	2455.870		
Accuracy	Pre	108.879	68.282	0.063	Negative
	Post	130.071	95.519		

Note: Results are based on strike styles used by participant.

As shown in Table 21, there was no significance for Participant 5. Central reaction time was approaching significance for a positive effect, and peripheral reaction time was approaching significance for a negative effect.

Table 21. *Results of Participant 5*

Metric	**Test**	**Mean**	***SD***	***P* Value**	**Effect**
TRT	Pre	0.889	0.156	0.111	Positive
	Post	0.858	0.157		
CNS	Pre	0.566	0.186	0.058	Positive
	Post	0.446	0.135		
PNS	Pre	0.325	0.086	0.087	Negative
	Post	0.413	0.141		
Max LP	Pre	1383.897	315.240	0.839	Positive
	Post	1393.318	377.231		
Avg LP	Pre	884.832	224.733	0.978	Negative
	Post	883.694	285.557		
Max RP	Pre	3397.565	3624.022	0.197	Positive
	Post	3702.542	4093.157		
Avg RP	Pre	2023.241	2281.910	0.511	Positive
	Post	2103.009	2461.920		
Max TP	Pre	4695.473	3709.028	0.162	Positive
	Post	5006.048	4093.752		
Avg TP	Pre	2908.072	2320.362	0.539	Positive
	Post	2986.705	2445.450		
Accuracy	Pre	125.984	80.017	0.375	Positive
	Post	119.083	75.539		

Note: Results are based on strike styles used by participant.

Participant 6 demonstrated a significant positive effect on central reaction time. This participant also exhibited a significant negative effect on average linear power. Maximum linear power was approaching significance with a negative effect.

Table 22. *Results of Participant 6*

Metric	**Test**	**Mean**	***SD***	***P* Value**	**Effect**
TRT	Pre	0.657	0.114	0.108	Positive
	Post	0.628	0.106		
CNS	Pre	0.408	0.085	*0.017	Positive
	Post	0.305	0.068		
PNS	Pre	0.250	0.071	0.124	Negative
	Post	0.325	0.121		
Max LP	Pre	156.740	75.621	0.061	Negative
	Post	123.455	52.573		
Avg LP	Pre	114.965	53.515	*0.026	Negative
	Post	97.203	48.523		
Max RP	Pre	875.608	1058.307	0.521	Negative
	Post	744.380	795.655		
Avg RP	Pre	704.395	1022.878	0.422	Negative
	Post	571.132	715.131		
Max TP	Pre	1002.447	1015.823	0.452	Negative
	Post	845.090	754.751		
Avg TP	Pre	819.360	1005.685	0.379	Negative
	Post	668.337	687.910		
Accuracy	Pre	65.650	46.226	0.690	Negative
	Post	70.347	33.305		

Note: Results are based on strike styles used by participant.

The final table depicts a highly significant positive effect for total reaction time for Participant 7. A significant positive effect on central reaction time and accuracy was also demonstrated.

Table 23. *Results of Participant 7*

Metric	**Test**	**Mean**	***SD***	***P* Value**	**Effect**
TRT	Pre	0.963	0.045	**0.000	Positive
	Post	0.815	0.059		
CNS	Pre	0.772	0.228	*0.013	Positive
	Post	0.490	0.089		
PNS	Pre	0.195	0.238	0.180	Negative
	Post	0.327	0.087		
Max LP	Pre	303.272	41.670	0.695	Positive
	Post	317.325	106.874		
Avg LP	Pre	216.505	42.145	0.750	Negative
	Post	210.468	78.942		
Max RP	Pre	3448.818	4105.165	0.596	Negative
	Post	3288.382	3562.615		
Avg RP	Pre	2258.350	3153.128	0.395	Negative
	Post	1715.958	1814.872		
Max TP	Pre	3678.388	4105.123	0.626	Negative
	Post	3526.093	3550.791		
Avg TP	Pre	2474.857	3170.425	0.398	Negative
	Post	1926.428	1831.204		
Accuracy	Pre	59.182	23.448	*0.041	Positive
	Post	45.432	17.209		

Note: Results are based on strike styles used by participant.

Chapter Summary

In this chapter, I have presented all of the results and multi layers of statistical analysis. This included the overall effect and then investigating this effect isolated to the upper and lower body. A further breakdown was depicted by examining a potential effect at the individual strike level and, lastly, the effects by individual participant. Effect trends and discussion points will be presented in the next chapter.

Chapter 5: Discussion

It is my aim in this chapter to present the novelty of this research and how it adds to the literature. Also, I intend to examine the trends demonstrated in the results at each stage of analysis for each metric and to compare them to existing conclusions in the literature. Lastly, this discussion will provide an insight on the implications for practitioners of mixed martial arts and suggestions for future research.

Pilot Investigation

Comparisons to conclusions from the literature will be few, as this investigation was the first of its kind in a variety of aspects regarding weight cutting. For example, this was the first study to use only mixed martial arts practitioners or striking performance in mixed martial arts. Another first involved the focus on striking performance from a biomechanical perspective. Finally, this study was the first to allow a full 24-hour rehydration and re-feed to represent the chronology of mixed martial arts weigh-ins and competitions.

More importantly, this study was the first to investigate weight cutting from the perspective of reaction time or accuracy. While the work was pilot in the previously listed areas, it was the third to allow a self-selected weight cutting regimen. Previous self-selected weight loss studies used dynamometers to assess work and strength and did not allow the 24-hour rehydration found in mixed martial arts (Oopik et al., 2002; Timpmann et al., 2008).

Overall Trends

The results indicated that there was a highly significant positive effect on total and central nervous reaction time, but a highly significant negative effect on peripheral reaction time (see Appendix C). That is, weight cutting unequivocally decreased the reaction time from the central nervous system from an overall pre- to post-perspective, which was in direct opposition to the hypothesis. However, peripheral reaction time from an overall perspective did increase, as hypothesized. The negative effect on peripheral reaction was overridden by the positive effect so much so that at the overall level of analysis, there was a highly significant positive effect on the total reaction time from this overall perspective. That is to say, there was a decrease in total reaction time. This was a rejection of the hypothesis. This suggests a mitigating effect of enough central recovery to nullify the peripheral reaction deficits.

Similarly, in rejection of the hypothesis, all metrics of power showed no significance. This null effect on power outputs is in line with the summary conclusion on the effect of weight cutting on power as presented by Horswill (2009). This conclusion was based across combative sports and was cited in chapter one: essentially stating that repeated short-duration high-intensity performances are less likely to be adversely effected. When combined with an element of endurance, which there was not in this investigation, power is more likely to show decrements. Given the measurements were investigating a compilation of single strikes, there was not an endurance element present in this study. However, accuracy was approaching significance with a negative effect. It was hypothesized that accuracy would be affected negatively.

In summary, the overall trends were that of an increase in peripheral reaction time and a decrease in central reaction time. The decrease in central reaction time was enough to diminish the decrease in peripheral reaction time so much so that there was a decrease in total reaction time. This suggests that a 24-hour recovery period between weighing in and competing is sufficient to allow cognitive recovery. This trend may not hold with increased weight lost or decreased recovery time.

Trends by Hand and Foot Strikes

When moving deeper into the data, shifting from an all-encompassing overview to accounting for differences between upper and lower body strikes, these trends remained (see Appendix D). For hand strikes, there was a highly significant positive effect on total reaction time and central reaction (i.e., decreased total and central reaction time) and a significant negative effect on peripheral reaction (i.e., increased peripheral reaction time). Foot strikes demonstrated the exact trends: that is, highly significant positive effect on total and central reaction time (i.e., decreased total and central reaction time) and a significant negative effect on peripheral reaction time (i.e., increased peripheral reaction time). Again, only the peripheral reaction time supported the hypothesis. Matching the overall trends, power and its components did not demonstrate significance, rejecting the hypothesis. Again, this matched the conclusion as presented by Horswill (2009) that power will not be affected in short-duration high-intensity movements.

In short, the overall trends were upheld, that is: a decrease in total and central reaction time and an increase in peripheral reaction time. The suggestion that 24 hours is enough to recover from this weight cut is maintained. However, would this continue with more weight lost or decreased recovery time?

Trends by Individual Strike

Reaction time components. Digging deeper into the data, the trends become less clear, suggesting variability in the effect of weight cutting by a selected strike style (see Appendix E). For reaction time trends, the significant (*) or highly significant (**)

positive effect (i.e., decreased reaction time) on total reaction time manifested for left hooks to the body (**), right straights to the head (*), and right kicks to the leg (*). Right hooks to the head and right kicks to the head were approaching a positive significance: that is, a decreased reaction time. Central reaction time demonstrated a significant positive effect for left hooks to the body (*) and right straights to the head (*). Right hooks to the head were approaching significance with a positive effect. The mitigating effect of faster central reaction covering up deficits in peripheral reaction appeared to wane at the individual strike. There was no significance on peripheral reaction time.

Power components. At this level of analysis, components of power began to approach or achieve significance (see Appendix E). There was no clear pattern appearing in the power components. Only left and right kicks to the body demonstrated a significant negative effect. Left kicks to the body had a significant negative effect on average rotational power. Right kicks to the body revealed a significant negative effect on maximum and average rotational powers as well as on maximum and average total powers. Both of these strikes saw a decrease in power. It should be noted that left straights to the head and right kicks to the body were approaching a negative significance in maximum linear power, while right hooks to the head were approaching negative significance for both maximum and average linear power. This provided mixed results and no conclusion on the effect on power by individual strike style.

Accuracy. Similar to power, accuracy began to occasionally show a negative effect (see Appendix E). There was a significant negative effect on right straights to the head, as well as right kicks to the head approaching a significant positive effect. This did not maintain the approaching trend found at the overall level and no conclusion on a negative effect on accuracy within strike style.

Trends by Individual Participant

Trends at the level of the participants are presented and discussed in relation to each individual. It needs to be noted that there were no clear consistent patterns (see Appendix F).

1. Participant 1 demonstrated a significant positive effect on central reaction time and a significant negative effect on accuracy. Total reaction time was approaching a positive significance.
2. Participant 2 depicted a positive effect approaching significance in central reaction time.
3. Participant 3 was approaching significance with a positive effect on total reaction time. There was also an approaching significance with a negative effect on maximum and average linear power.
4. Participant 4 was approaching a positive significance for total reaction time. Also, there was an approaching negative significance for maximum linear power and accuracy.
5. Participant 5 was approaching significance in the positive direction for central reaction time and in the negative direction for peripheral reaction time.
6. Participant 6 demonstrated a significant positive effect on central reaction time. Maximum linear power was approaching a negative significance, and average linear power demonstrated a negative significance.

7. Participant 7 portrayed a highly significant positive effect on total reaction time. Central reaction time demonstrated a significant positive effect and, as an outlier, demonstrated a significant positive effect on accuracy.

These results have demonstrated a large variability between subjects. However, the overall trends of decreased total and central reaction time continually appeared. This individual variability at the participant level suggests that certain athletes are better able to handle or recover from dehydration. An athlete will develop their own habits and comforts with weight loss and, like any learning, should improve with each successive attempt at the practice.

Conclusion

These findings suggest a large variability in all metrics on the effect of weight cutting based on not only strike style, but also on participant. This notion of individual ability to tolerate weight loss was presented in the only two studies to have investigated striking performance related to weight cutting. Both studies were focused on boxers and did not include any recovery time post weight cut. While both found a negative effect on striking performance, the concept that some individuals appeared predisposed to better handle dehydration and not demonstrate performance decrements was put forward (M. S. Smith et al., 2000). Similarly, this investigation confirmed some athletes demonstrate no decrement and may even improve performance (M. Smith et al., 2001). It should be noted that both studies used padding over a force plate as their measurement of performance.

This investigation expanded on the concept of performance, including not just power components, but the movement component of peripheral reaction time and the cognitive elements of central reaction time and accuracy. In that regard, an overall negative effect on peripheral reaction time and a positive effect on total reaction time were found. However, there appeared to be a mitigating effect of central reaction time decreasing enough to override the negative effect on peripheral reaction time. It is worth noting that peripheral reaction time and accuracy only had a positive significant effect once across the 12 strike styles and seven subjects

This suggests that a 24-hour time window of recovery appears to be enough to recover central reaction time and muscular power, but not peripheral reaction from a 5% weight cut. As stated earlier, the results on power were inconclusive, reaffirming the conclusion put forward by Horswill (2009). That is that in a repeated short-duration high-intensity performance, power is less likely to be affected adversely.

It is of interest that all eight participants not in a real competition articulated that the weight lost for a 5% body weight was far less than their normal practices for competition, and most suggested they could lose the 5% in a matter of hours. The protocol required them to use at least 24 hours to cut weight. The remaining four were in real competition, where three did not need a full 5% reduction to achieve their weight class. The last competitor lost 18% of his body weight to achieve his necessary weigh in.

Also, for the four participants in real competition, as the researcher, I had a concern about interfering with pre competition/game day habits. Each competitor stated sentiments regarding enjoying the distraction of being a test subject and that the testing helped take their minds off of the impending “fight”, reducing anxiety and stress.

Implications for Practitioners

The findings of this investigation suggest that weight cutting can be used as a practice with little detriment if used sparingly and in moderation. Potential detriments associated with a 5% body weight reduction or less appear to be able to be mitigated by the allotted 24-hour period between weigh-ins and competition in all measured areas except peripheral reaction time. As stated earlier, this effect seems to be compensated by a decrease in central reaction time.

These findings might lead athletes and participants to consider utilizing weight cutting practices because of the decreased reaction times, but with slower muscular movements (i.e., peripheral reaction time), the ability to physically keep up with the mental strategies and reactions could be detrimental. For example, upon seeing an opening, an athlete might be unable to effectively capitalize on said defensive opening. Another example could be an athlete seeing an incoming attack and being unable to effectively move out of range, block, and/or counter in time.

Implications for Future Research

Further research is needed to expand on the phenomenon of weight cutting and striking performance. Firstly, to reduce the variation in power outputs, participants could be limited to a singular weight class. With power being linked to body weight, isolating to a single weight class would allow a more accurate investigation. Also, a weight cut larger than 5% of body weight as well as further studies into the effect on reaction time and accuracy is recommended. Correspondingly, I suggest a more effective test could be applied more efficiently in the competition setting to avoid laboratory-mandated weight loss and investigate the phenomenon in its real life setting. Lastly, future research could isolate within a single common strike style to provide more homogenous data.

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Appendix A: Ethics Application Approval

UNIVERSITY OF LETHBRIDGE
APPLICATION FOR ETHICAL REVIEW OF HUMAN SUBJECT RESEARCH

The Human Subject Research Committee is mandated by University policy to examine and approve research proposals to ensure that ethical principles and standards respecting the personal welfare and rights of subjects have been recognized and accommodated. The Committee follows the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans. This Policy Statement is available at: http://www.pre.ethics.gc.ca/english/policystatement/policystatement.cfm. Other guidelines may be used when appropriate to the research in question.

You are encouraged to speak with the Office of Research Services about any outstanding issues, and seek the advice of the Committee when appropriate.

You are asked to respond to all of the following items and **to submit your application and all supporting documents electronically to Margaret McKeen, Office of Research Services.** (If possible, please use a different font for your responses, and submit your application as one document including the supporting documentation.) Supporting documents include letters of introduction, interview questions, questionnaires, telephone survey scripts, letters of consent, etc.

The Committee deals with applications as expeditiously as possible. **Please allow up to one month from the date of receipt for Committee review**.

Following approval of your protocol, any changes in procedures relevant to the ethical issues involved in the treatment of human subjects are to be reported immediately to the Office of Research Services.

If the research involves invasive procedures, a Hazard Assessment Report (available from Risk and Safety Services or on-line at: http://www.uleth.ca/hum/ohs/Documents/HAZARD_ASSESSMENT_FORM.doc) must be completed and submitted to Risk and Safety Services for approval. Review and approval by the Biosafety Committee may also be required.

SECTION A: GENERAL *(This information is required for administrative purposes only and will not affect the ethical review of your proposal.)*

A1. Researcher/Applicant Information

Name: Jared Evans
Department: Kinesiology
Telephone Number: home [phone #] campus [phone #]
Email address: [email address]
Are you: Graduate Student

A2. Supervisor Information

Name: Dr. Gongbing Shan
Department: Kinesiology
Telephone Number: [phone #]
Email address: [email address]
Are you: Faculty

A3. Student Thesis/Project Committee

a) Is this research for an undergraduate or graduate thesis/project? **Yes**

b) If yes, please provide the names, departments and phone numbers of your Committee members.

Name:	Department:	Telephone:
1. Dr. Gongbing Shan	Kinesiology	[phone #]
2. Dr. Jochen Bocksnick	Kinesiology	[phone #]
3. Dr. Hua Li	Math & Comp Science	[phone #]

A4. Title of Project:

Indicate the title of your project. If this project is funded, the title should be the same as the title of your funded research.

Msc. Kinesiology – The influence of weight fluctuation on biomechanical characteristics in martial arts performance

A5. Location of Research

a) Indicate where the research will be conducted.

The University of Lethbridge Biomechanics Lab (Pe 240) in the Kinesiology Department.

b) Does this project involve other centers, jurisdictions or countries? If so, please provide a list of the other groups who will be reviewing this protocol.

N/A

A6. Start/End Dates of Research Involving Human Subjects

Please state the start and end dates of the research involving human subjects. **NOTE: Research involving human subjects cannot begin until Human Subject Research Committee approval has been received.**

Start date (dd/mm/yyyy): 01/05/2009

End date (dd/mm/yyyy): 30/04/2010

A7. Funding

a) Is the project funded? No

b) Is the project part of a course? No

SECTION B: DETAILS ABOUT THE PROJECT

B1. Purpose of Project

Provide a brief and clear statement of the context and objectives of the project, including the key questions and/or hypotheses of the project (in two pages or less).

This study will examine the effect of weight fluctuations on biomechanical parameters of martial arts performance. These weight fluctuations take approximately one to two weeks depending on the competition (desired weight class) and coaching instruction. The parameters being investigated include reaction time, striking accuracy, power, speed, and balance. This research will contribute to the growing body of research on intentional weight fluctuation within sport and will help to supply scientific evidence for evaluating the phenomena of weight cutting within martial arts competition. It is hypothesized that a weight cut will weaken the power, slow down reaction and decrease the strike accuracy.

B2. Description of Subjects

a) Describe the subjects to be included (including age range, gender, minority status, and any other relevant characteristics). If appropriate, specify the number of subjects in each study group.

20-25 subjects depending on availability. These subjects being trained mixed martial artists from the local “Canadian Martial Arts Centre” or martial artists who are interested in the study through word of mouth. Experience, age and gender are not factors in this research and subjects’ inclusion is based on the availability of the athletes. Previous health conditions are controlled by the club and should not be a factor on this research. Based on an estimation of the clientele of the martial arts clubs there should be an adequate base of volunteers to draw subjects from.

b) List any subject inclusion/exclusion criteria.

N/A.

c) If the subjects or facilities will be offered compensation or credit for participating in the research, provide details. Specify the amount, what the compensation is for, and how payment will be determined for subjects who do not complete the study.

The volunteer subjects are not offered monetary compensation; it is entirely volunteer based on the signed consent form. The subjects’ are offered scientific feedback (biomechanical analysis) about their abilities in relation to sporting standards and to top level athletes within their sport. Also, 3D electrical reports can be created of subjects’ performance on request basis. The PI will create these reports free of charge.

B3. Recruitment of Subjects

a) Briefly describe how subjects will be recruited and who will be doing the recruiting. If posters, newspaper advertisements, radio announcements or letters of invitation are being used, append to this application.

Subjects are recruited through personal contact at the martial arts centre as well as word of mouth between the athletes. I am a member of the club and have personal contact with many of the athletes at the club. Relationships range from friends to training partners to acquaintances and I should be able to garner enough participants because the coach/owner of the club is aiding and involved with recruitment. Recruitment is not limited to this one club as all combat athletes are welcome.

b) When and how will people be informed of the right to withdraw from the study? What procedures will be followed for people who wish to withdraw at any point during the study? What happens to the information contributed to the point of withdrawal?

The subjects are participating on a volunteer basis and are informed of their right to withdraw at any time, prior to involvement. Since the testing is only two weeks at maximum, withdrawal will not significantly affect the database (ie. New recruitment will be used). A withdrawal would cause the subjects data to be excluded from the database.

c) Indicate how subjects can obtain feedback on the research findings.

Subjects can contact me through personal phone or email as well as verbal questions at the martial arts centre during training. My contact information is on the consent form (pg. 2).

B4. Description of Research Procedures

Provide a summary of the design and procedures of the research. Provide details of data collection, and time commitment for the subjects, etc. NOTE: all study measures (e.g. questionnaires, interview guides, surveys, rating scales, etc.) must be appended to this application. If the procedures include a blind, indicate under what conditions the code will be broken, what provisions have been made for this occurrence, and who will have the code.

Using subjects available from the martial arts club, a pre-test and post-test data collection will be applied. These tests are performed prior to and after the initiation of a self-selected regime for weight reduction and weight regain, as deemed by the sport, coaches and personal experience; weight fluctuation is not manipulated by the researcher. The subjects' record their individual procedures, methods, and chronological weight fluctuation over these one or two weeks (depending on personal plan). These tests are approximately 1 hour per session for two sessions approximately one to two weeks apart and have the subject performing selected martial arts strikes on a standard punching bag. This performance will be analyzed by a synchronized data collection of 3D motion capture, ground reaction forces and electromyography (EMG). 3D motion capture consists of a 12 high speed camera system (VICON v8i at 250 frames/s) and will be used to collect total body motion of both subject and punching bag. Ground reaction forces are measured using 2 Kistler force platforms for determining weight transfer during the skill performance. Surface EMG is measured using a wireless Noraxon Telemyo8 system synchronized with the motion capture system to monitor the major muscle groups in the striking limbs; biceps, triceps, quadriceps and hamstrings. This potentially requires a small patch of skin to be shaved for better skin-electrode contact. This allows an investigation of muscular recruitment, activation and onset differences. Statistical analyses will be performed to determine the influence of weight fluctuations on martial arts performance. These analyses include descriptive statistics for group characterization and t-tests for determining the influence on biomechanical parameters.

B5. Privacy Protection

The next set of questions deals with anonymity and confidentiality. Refer to the brief descriptions below to assist you in answering these questions.

a) ***Anonymity*** *refers to the protection of the identity of participants. Anonymity can be provided along a continuum, from "complete" to "no" protection, where complete protection means that no identifying information will be collected.*

1. Will the anonymity of the participants be protected?

Yes (completely)

2. If "yes", explain how anonymity will be protected, and describe how this will be explained in the consent process.

The information collected will be stored by initials and on a separate hard drive location (finally stored on the researcher's personal external hard drive). The tests are recorded with a standard video camera, but the view is slightly from behind and this data is only seen by the researcher. The 12 camera system does not record subjects' faces. Discussion of results and findings will occur through private means (phone or email) or through private one on one communications. The researcher will not show the comparison among athletes during the communication.

3. If "no", justify why loss of anonymity is required, and describe how this will be explained in the consent process.

b) ***Confidentiality*** *refers to the protection, access, control and security of the data and personal information.*

1. How will confidentiality be protected and how will this be explained in the consent process? Specify which personnel will have access to the listing of names and study ID numbers as well as other study information collected (use job titles rather than individual names). Provide details on the location, manner of storage, and the proposed retention period of the information collected.

All personal information collected is stored in the researcher's files and will not be disclosed without subject permission. The raw data and consent forms will be stored in a separate and locked cabinet for three years that both the researcher and supervisor have access to.

B6. Potential Risks and Benefits

To facilitate Human Subject Research Committee review and to determine whether the study involves more than minimal risk, please respond to the following questions. Does this project involve…	Check those that apply
1. Collection of data through invasive clinical procedures that are not required for normal patient care.	
2. Collection of data through noninvasive clinical procedures involving imaging or microwaves that are not required for normal patient care.	
3. Collection, use, or disclosure of health information or biological samples where the researcher is requesting that the requirement for informed consent be waived.	
4. Any procedures involving deception or incomplete disclosure of the nature of the research for purposes of informed consent.	
5. Any possibility that a breach of confidentiality could place subjects at risk of Criminal or civil liability or be damaging to subjects' financial standing, Employability or reputation.	
6. Research questions or procedures that might be expected to cause subject psychological distress, discomfort or anxiety beyond what a reasonable person might expect in day to day social interactions (e.g., questions that raise painful memories or unresolved emotional issues).	
7. Research questions that involve sensitive issues (e.g. sexual orientation or practices, etc.).	
8. Investigations in which there is an existing relationship between the investigator and subjects (e.g., manager/employee, therapist/client, teacher/student).	
9. Investigations in which there is a conflict of interest between an investigator and the sponsor of the investigation.	
10. Any other non-therapeutic risks that arise from procedures not directly related to patient care.	

a) Outline any risks of potential physical or emotional harm or discomfort to the subjects, and describe how the anticipated benefits outweigh the potential risks.

There are no associated risks with this research; however, this study is relevant practically because it will supply scientific evidence for evaluating weight fluctuation in weight class sports and also individual athletes' health within these sports. Since the athletes are medically approved (by the competition commission) and are ready to participate in competition, the biomechanical tests have no health risks to the planned competitive performance.

b) Indicate the steps taken to inform subjects of the possible consequences of releasing information in the public domain, and describe how subjects will be given an opportunity to review material before it is released.

The PI will be using the results and data analysis for research presentations, however, subjects' identity will remain confidential.

B7. Obtaining Consent

Advise the Committee how informed consent will be obtained. The Tri-Council Policy Statement ensures that informed consent be obtained in writing from all subjects or, when appropriate from parents or legal guardians, unless there is a good reason for not doing so. If a consent form will be used, attach copies for the Committee. A **sample letter of consent** is available from the Office of Research Services or our web site at: http://www.uleth.ca/rch/funding/forms/Human_Subject_Research_Sample_Letter_of_Consent.pdf. Please ensure that the reading level of the consent form is appropriate to the population involved.

a) Clearly detail who will be obtaining consent and the procedures for doing so. If appropriate, specify whether subjects will be randomly assigned to groups before or after consent has been attained.

The researcher will be obtaining consent from individuals as they express interest in the study (or are approached to garner interest), collecting signatures before testing.

b) If the subjects are not able/competent to give fully informed consent (cognitive impairment, age, etc.), or if there are significant power differences in operation (professor/student, employer/employee, political or economic minorities, etc.), please specify, and describe steps you will take to obtain free and informed consent. If participants are not competent to consent, specify who will consent on their behalf.

N/A

c) Do any of the procedures include the use of deception or partial disclosure of information to subjects? If yes, provide a rationale for the deception or partial disclosure. Describe the procedures for debriefing the subjects.

N/A

d) For the letter of consent/consent form:

attached at the end

B8. Continuing Review

Propose a process for continuing review if the research is ongoing. Continuing review should consist of, at least, the submission of a succinct annual status report. Notify the Committee when the research concludes.

The data collection is approximately one year, if that time frame is exceeded, an annual review will be conducted.

The protection of human subjects will be assured in accordance with the Tri-Council Policy Statement or with other guidelines if these have been agreed upon as more appropriate.

Signature of Researcher/Applicant	Date

(Revised April 3/09)

Appendix B: Consent Form

The Influence of Weight Fluctuation on Biomechanical Characteristics in Martial Arts Performance

Biomechanics Laboratory
University of Lethbridge

I, Jared Evans (B.Sc. Exercise Science) invite you to participate in my Masters research under the supervision of Dr. Shan (Ph.D.; Department of Kinesiology) to scientifically evaluate the effect of weight fluctuations on biomechanical characteristics of martial arts performance. If you would like to do a weight fluctuation for mock competition and/or training; your participation is appreciated.

Purpose

The aim is to investigate issues related to weight cutting in martial arts competition such as if the practice is needed and if it is effective for increasing the chance to win when taking on potential health risks and/or performance decrements. This study is focused on the influence of weight cutting on power, accuracy, balance and reaction time in regard to individual strike performance.

Procedures

A pre-test will be performed prior to the weight fluctuation. A post-test will be performed after the fluctuation when you have returned to a competition state 24 hours after making weight. Each testing session takes approximately 60 minutes and will have you performing selected strikes on a punching bag while standing on force platforms. The strikes include a variety of punches and kicks at different targets. The same data collection procedure and measurement of biomechanical parameters will be applied to both the pre- and post-test.

These performances will be analyzed by a synchronized data collection of 3D motion capture, ground reaction forces and electromyography (EMG). 3D capture consists of a 12 high speed camera system (VICON 200 Hz) utilizing passive markers attached to a special suit and will be used to collect total body motion of both you and the punching bag. Ground reaction forces are measured using 2 Kistler force platforms and used for determining weight transfer and body sway. Surface EMG is measured using a wireless Noraxon Telemyo8 system to monitor the major muscle groups in the striking limbs; biceps, triceps, quadriceps and hamstrings. This allows an investigation of reaction time, strike time, muscular recruitment, muscular activation and onset differences.

Potential Risks and Discomforts

It should be noted that a small patch of skin may need to be shaved for proper electrode skin contact. Nothing is intrusive and these tests do not use any sort of medication. There are no risks and discomforts associated with the testing set up and/or protocol.

Potential Benefits

Benefits of participation include; scientific feedback (biomechanical analysis) on your abilities in relation to sporting standards and top level athletes within your sport as well as the potential decrement in your abilities due to practices involved in “making weight”. This includes power, accelerations, velocities, force and momentum. Also, you will help to supply scientific evidence for evaluating weight fluctuation in weight class sports. Lastly, 3D electrical reports can be created of your performance on a request basis, free of charge.

Participation and Withdrawal

Participation in this study is entirely voluntary and you are free to withdraw at any time. Your data will not be used should you withdraw from the study.

Confidentiality

Only the primary researchers will have access to the data collected. Therefore your anonymity and confidentiality will be secure. Names will not be used during data processing and data is saved on a project hard drive that is only accessible by the researchers. While 3D motion does not capture facial features, regular video is taken but not shared with anyone or utilized past the early stages of analysis.

Information about Study Results

If you have any further questions, concerns or result requests please contact:
Jared Evans work: [phone #], cell: [phone #], [email address]
Dr. Shan: [phone #], [email address]

This study has been reviewed by the University of Lethbridge Human Subject Research Committee. Questions regarding your rights as a participant in this research may be addressed to the Office of Research Services, University of Lethbridge (Phone: [phone #]).

Your signature below indicates that you have read and understood the information provided above, that you are willing to participate in this study and that you understand that you may withdraw at any time.

I have read the attached informed consent form and I consent to participate in the "The influence of weight fluctuation on biomechanical characteristics in martial arts performance" research study.

Printed Name: ___________________________ Date: _____________________

Signature: ______________________________

Witnessed by: ___________________________ Date: ______________________

Appendix C: SPSS Statistical Results for Over All Effect

Central Tendency for Overall Effect

Performance Metric	Test	*N*	Mean	*SD*	Std. Error Mean
TRT	Pre	58	.806	.202	.026
	Post	58	.755	.185	.024
CNS	Pre	58	.549	.213	.028
	Post	58	.442	.155	.020
PNS	Pre	58	.259	.152	.020
	Post	58	.314	.128	.017
Max LP	Pre	58	664.528	524.150	68.824
	Post	58	1745.196	5920.441	777.392
Avg LP	Pre	58	424.996	323.286	42.450
	Post	58	836.453	2257.936	296.482
Max RP	Pre	58	2720.526	3052.292	400.786
	Post	58	3033.568	3613.414	474.465
Avg RP	Pre	58	1789.452	2211.606	290.398
	Post	58	1736.275	2039.300	267.773
Max TP	Pre	58	3295.677	3173.176	416.658
	Post	58	4704.821	8183.933	1074.603
Avg TP	Pre	58	2214.449	2272.025	298.331
	Post	58	2572.729	3409.679	447.713
Accuracy	Pre	58	97.687	67.242	8.829
	Post	58	104.972	74.310	9.757

T-Test Results for Overall Effect

Metric	Paired Differences					t	df	Sig. (2-tailed)
	Mean	*SD*	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
TRT	.051	.069	.009	.033	.069	5.646	57	.000
CNS	.107	.157	.021	.066	.149	5.194	57	.000
PNS	-.055	.136	.018	-.091	-.019	-3.083	57	.003
Max LP	-1080.668	5976.147	784.707	-2652.016	490.680	-1.377	57	.174
Avg LP	-411.457	2285.699	300.127	-1012.451	189.537	-1.371	57	.176
Max RP	-313.042	2208.642	290.009	-893.774	267.691	-1.079	57	.285
Avg RP	53.177	1243.503	163.280	-273.786	380.139	.326	57	.746
Max TP	-1409.144	8046.381	1056.542	-3524.832	706.544	-1.334	57	.188
Avg TP	-358.280	3242.036	425.700	-1210.730	494.170	-.842	57	.404
Accuracy	-7.285	28.721	3.771	-14.837	.267	-1.932	57	.058

Appendix D: SPSS Tables for Overall Hand and Foot Strikes

Central Tendency for Overall Hand Strikes

Performance Metric (Hand)	Test	*N*	Mean	*SD*	Std. Error Mean
TRT	Pre	41	.756	.214	.033
	Post	41	.702	.189	.029
CNS	Pre	41	.500	.220	.034
	Post	41	.401	.152	.024
PNS	Pre	41	.257	.164	.026
	Post	41	.301	.117	.018
Max LP	Pre	41	485.843	401.075	62.637
	Post	41	2005.947	7041.772	1099.740
Avg LP	Pre	41	333.080	275.107	42.964
	Post	41	902.543	2683.092	419.029
Max RP	Pre	41	2429.657	3058.301	477.626
	Post	41	2785.409	3613.540	564.340
Avg RP	Pre	41	1659.771	2346.485	366.459
	Post	41	1554.745	1995.528	311.649
Max TP	Pre	41	2859.830	3183.502	497.180
	Post	41	4743.050	9502.096	1483.978
Avg TP	Pre	41	1992.852	2414.467	377.076
	Post	41	2457.288	3843.922	600.320
Accuracy	Pre	41	59.810	27.904	4.358
	Post	41	65.200	28.653	4.475

T-Test Results for Overall Hand Strikes

Metric	Paired Differences					t	df	Sig. (2-tailed)
	Mean	*SD*	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
TRT	.054	.076	.012	.030	.077	4.549	40	.000
CNS	.099	.151	.024	.052	.147	4.223	40	.000
PNS	-.044	.128	.020	-.084	-.003	-2.188	40	.035
Max LP	-1520.104	7086.042	1106.654	-3756.734	716.527	-1.374	40	.177
Avg LP	-569.463	2711.972	423.539	-1425.467	286.541	-1.345	40	.186
Max RP	-355.752	2555.603	399.118	-1162.400	450.896	-0.891	40	.378
Avg RP	105.027	1431.836	223.615	-346.916	556.970	.470	40	.641
Max TP	-1883.219	9542.438	1490.278	-4895.184	1128.746	-1.264	40	.214
Avg TP	-464.436	3845.098	600.503	-1678.098	749.227	-.773	40	.444
Accuracy	-5.391	21.824	3.408	-12.280	1.498	-1.582	40	.122

Central Tendency for Overall Foot Strikes

Performance Metric (Foot)	Test	*N*	Mean	*SD*	Std. Error Mean
TRT	Pre	17	.928	.089	.021
	Post	17	.884	.091	.022
CNS	Pre	17	.666	.143	.035
	Post	17	.539	.116	.028
PNS	Pre	17	.262	.122	.030
	Post	17	.345	.152	.037
Max LP	Pre	17	1095.474	545.386	132.275
	Post	17	1116.327	557.332	135.173
Avg LP	Pre	17	646.677	330.543	80.168
	Post	17	677.061	356.321	86.421
Max RP	Pre	17	3422.035	3011.194	730.322
	Post	17	3632.068	3651.319	885.575
Avg RP	Pre	17	2102.210	1874.275	454.578
	Post	17	2174.084	2138.248	518.601
Max TP	Pre	17	4346.838	2978.838	722.474
	Post	17	4612.623	3587.115	870.003
Avg TP	Pre	17	2748.887	1840.252	446.327
	Post	17	2851.144	2088.410	506.514
Accuracy	Pre	17	189.038	40.227	9.757
	Post	17	200.891	61.572	14.933

T-Test Results for Overall Foot Strikes

Metric	Paired Differences					*t*	*df*	Sig. (2-tailed)
	Mean	*SD*	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
TRT	.044	.049	.012	.019	.070	3.684	16	.002
CNS	.126	.176	.043	.036	.217	2.966	16	.009
PNS	-.083	.156	.038	-.163	-.003	-2.198	16	.043
Max LP	-20.853	118.748	28.801	-81.907	40.201	-0.724	16	.479
Avg LP	-30.384	82.154	19.925	-72.623	11.856	-1.525	16	.147
Max RP	-210.034	1017.110	246.686	-732.983	312.916	-0.851	16	.407
Avg RP	-71.874	599.834	145.481	-380.280	236.533	-.494	16	.628
Max TP	-265.785	1020.382	247.479	-790.417	258.847	-1.074	16	.299
Avg TP	-102.257	619.880	150.343	-420.970	216.456	-.680	16	.506
Accuracy	-11.852	41.433	10.049	-33.155	9.450	-1.179	16	.255

Appendix E: Tables by Individual Strike Style

Central Tendency for Left Hook to Body

	Test	*N*	Mean	*SD*	Std. Error Mean
TRT	Pre	7	.836	.258	.097
	Post	7	.763	.224	.085
CNS	Pre	7	.667	.323	.122
	Post	7	.453	.177	.067
PNS	Pre	7	.167	.194	.073
	Post	7	.309	.071	.027
Max LP	Pre	7	560.544	377.135	142.544
	Post	7	525.161	412.926	156.071
Avg LP	Pre	7	374.866	277.921	105.044
	Post	7	359.897	296.801	112.180
Max RP	Pre	7	318.034	237.347	89.709
	Post	7	219.377	225.870	85.371
Avg RP	Pre	7	176.107	145.710	55.073
	Post	7	126.556	145.266	54.906
Max TP	Pre	7	808.593	483.843	182.876
	Post	7	692.747	551.097	208.295
Avg TP	Pre	7	550.976	373.054	141.001
	Post	7	486.451	413.981	156.470
Accuracy	Pre	7	46.276	22.505	8.506
	Post	7	60.104	34.314	12.970

T-Test Results for Left Hook to the Body

Metric	Paired Differences					*t*	*df*	Sig. (2-tailed)
	Mean	*SD*	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
TRT	.073	.044	.017	.032	.113	4.395	6	.005
CNS	.214	.210	.079	.020	.408	2.704	6	.035
PNS	-.141	.194	.073	-.321	.038	-1.926	6	.102
Max LP	35.383	121.351	45.867	-76.849	147.614	0.771	6	.470
Avg LP	14.969	63.013	23.817	-43.309	73.246	0.628	6	.553
Max RP	98.657	157.624	59.576	-47.121	244.435	1.656	6	.149
Avg RP	49.551	79.081	29.890	-23.587	122.689	1.658	6	.148
Max TP	115.846	169.128	63.925	-40.572	272.263	1.812	6	.120
Avg TP	64.524	100.344	37.926	-28.278	157.327	1.701	6	.140
Accuracy	-13.829	25.561	9.661	-37.468	9.811	-1.431	6	.202

Central Tendency for Left Hook to Head

	Test	*N*	Mean	*SD*	Std. Error Mean
TRT	Pre	7	0.767	0.247	0.093
	Post	7	0.731	0.227	0.086
CNS	Pre	7	0.540	0.201	0.076
	Post	7	0.459	0.272	0.103
PNS	Pre	7	0.230	0.142	0.054
	Post	7	0.276	0.097	0.037
Max LP	Pre	7	370.074	337.467	127.551
	Post	7	4314.030	10478.447	3960.481
Avg LP	Pre	7	249.591	242.317	91.587
	Post	7	1773.937	4111.434	1553.976
Max RP	Pre	7	1004.639	568.985	215.056
	Post	7	2257.729	3473.166	1312.733
Avg RP	Pre	7	470.214	201.842	76.289
	Post	7	956.370	1350.783	510.548
Max TP	Pre	7	1342.529	716.055	270.643
	Post	7	6547.910	13923.661	5262.649
Avg TP	Pre	7	719.806	414.645	156.721
	Post	7	2730.310	5455.911	2062.141
Accuracy	Pre	7	70.007	34.358	12.986
	Post	7	65.653	25.793	9.749

T-Test Results for Left Hook to the Head

Metric	Paired Differences					*t*	*df*	Sig. (2-tailed)
	Mean	*SD*	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
TRT	.036	.071	.027	-.030	.101	1.337	6	.230
CNS	.081	.163	.062	-.069	.232	1.324	6	.234
PNS	-.046	.163	.062	-.197	.105	-0.741	6	.487
Max LP	-3943.956	10569.415	3994.863	-13719.034	5831.123	-0.987	6	.362
Avg LP	-1524.346	4177.838	1579.074	-5388.202	2339.510	-0.965	6	.372
Max RP	-1253.090	3704.555	1400.190	-4679.232	2173.052	-0.895	6	.405
Avg RP	-486.156	1472.069	556.390	-1847.592	875.281	-.874	6	.416
Max TP	-5205.381	14267.019	5392.426	-18400.173	7989.410	-0.965	6	.372
Avg TP	-2010.504	5646.332	2134.113	-7232.491	3211.482	-.942	6	.383
Accuracy	4.354	26.690	10.088	-20.330	29.039	0.432	6	.681

Central Tendency for Left Straight to the Head

	Test	*N*	Mean	*SD*	Std. Error Mean
TRT	Pre	7	0.650	0.244	0.092
	Post	7	0.599	0.156	0.059
CNS	Pre	7	0.544	0.287	0.109
	Post	7	0.416	0.131	0.049
PNS	Pre	7	0.110	0.060	0.023
	Post	7	0.181	0.047	0.018
Max LP	Pre	7	349.044	250.766	94.781
	Post	7	313.649	229.737	86.832
Avg LP	Pre	7	201.547	119.776	45.271
	Post	7	193.076	133.511	50.463
Max RP	Pre	7	1081.191	470.246	177.736
	Post	7	1019.314	439.239	166.017
Avg RP	Pre	7	655.017	290.283	109.717
	Post	7	580.461	249.451	94.284
Max TP	Pre	7	1313.283	564.894	213.510
	Post	7	1235.690	547.648	206.991
Avg TP	Pre	7	856.566	362.292	136.933
	Post	7	773.537	352.948	133.402
Accuracy	Pre	7	53.459	19.909	7.525
	Post	7	60.450	25.495	9.636

T-Test Results for Left Straight to the Head

Metric	Paired Differences					*t*	*df*	Sig. (2-tailed)
	Mean	*SD*	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
TRT	.051	.109	.041	-.050	.152	1.247	6	.259
CNS	.129	.183	.069	-.041	.298	1.859	6	.112
PNS	-.071	.104	.039	-.168	.025	-1.809	6	.120
Max LP	35.396	39.885	15.075	-1.492	72.284	2.348	6	.057
Avg LP	8.471	27.376	10.347	-16.848	33.790	0.819	6	.444
Max RP	61.877	307.801	116.338	-222.791	346.545	0.532	6	.614
Avg RP	74.556	190.590	72.036	-101.710	250.822	1.035	6	.341
Max TP	77.593	274.240	103.653	-176.037	331.222	0.749	6	.482
Avg TP	83.029	179.917	68.002	-83.367	249.424	1.221	6	.268
Accuracy	-6.991	12.015	4.541	-18.103	4.120	-1.540	6	.175

Central Tendency for Right Hook to the Body

	Test	*N*	Mean	*SD*	Std. Error Mean
TRT	Pre	6	0.757	0.157	0.064
	Post	6	0.722	0.119	0.049
CNS	Pre	6	0.405	0.128	0.052
	Post	6	0.360	0.072	0.029
PNS	Pre	6	0.353	0.082	0.034
	Post	6	0.362	0.068	0.028
Max LP	Pre	6	609.013	479.882	195.911
	Post	6	6651.842	14730.275	6013.610
Avg LP	Pre	6	462.477	385.689	157.457
	Post	6	2728.173	5464.906	2231.038
Max RP	Pre	6	304.828	338.262	138.095
	Post	6	2435.572	4796.890	1958.322
Avg RP	Pre	6	204.240	224.454	91.633
	Post	6	1045.803	1794.272	732.508
Max TP	Pre	6	885.572	576.510	235.359
	Post	6	9046.593	19494.477	7958.587
Avg TP	Pre	6	666.718	449.817	183.637
	Post	6	3773.977	7215.257	2945.616
Accuracy	Pre	6	73.502	45.377	18.525
	Post	6	70.760	39.500	16.126

T-Test Results for Right Hook to Body

Metric	Paired Differences					*t*	*df*	Sig. (2-tailed)
	Mean	*SD*	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
TRT	.035	.101	.041	-.071	.141	0.851	5	.434
CNS	.045	.132	.054	-.094	.184	0.832	5	.443
PNS	-.008	.062	.025	-.074	.057	-0.327	5	.757
Max LP	-6042.828	14863.578	6068.030	-21641.197	9555.540	-0.996	5	.365
Avg LP	-2265.697	5577.741	2277.103	-8119.177	3587.784	-0.995	5	.365
Max RP	-2130.743	4893.679	1997.836	-7266.344	3004.857	-1.067	5	.335
Avg RP	-841.563	1841.509	751.793	-2774.109	1090.982	-1.119	5	.314
Max TP	-8161.022	19750.646	8063.167	-28888.053	12566.010	-1.012	5	.358
Avg TP	-3107.258	7409.545	3024.934	-10883.099	4668.582	-1.027	5	.351
Accuracy	2.742	24.785	10.119	-23.269	28.752	0.271	5	.797

Central Tendency for Right Hook to the Head

	Test	*N*	Mean	*SD*	Std. Error Mean
TRT	Pre	7	0.820	0.196	0.074
	Post	7	0.756	0.223	0.084
CNS	Pre	7	0.406	0.111	0.042
	Post	7	0.349	0.076	0.029
PNS	Pre	7	0.414	0.144	0.054
	Post	7	0.406	0.165	0.062
Max LP	Pre	7	433.897	414.034	156.490
	Post	7	357.444	330.166	124.791
Avg LP	Pre	7	368.884	314.576	118.898
	Post	7	303.290	254.666	96.255
Max RP	Pre	7	7479.267	2952.930	1116.103
	Post	7	6861.971	3840.576	1451.601
Avg RP	Pre	7	6102.483	2173.835	821.632
	Post	7	4574.767	2407.993	910.136
Max TP	Pre	7	7878.394	3193.736	1207.119
	Post	7	7195.089	4059.444	1534.325
Avg TP	Pre	7	6471.367	2323.728	878.287
	Post	7	4878.054	2614.687	988.259
Accuracy	Pre	7	57.280	18.466	6.979
	Post	7	55.669	13.513	5.107

T-Test Results for Right Hook to the Head

Metric	Paired Differences					t	df	Sig. (2-tailed)
	Mean	SD	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
TRT	.064	.077	.029	-.007	.136	2.203	6	.070
CNS	.057	.075	.028	-.012	.126	2.016	6	.090
PNS	.009	.066	.025	-.053	.070	0.343	6	.744
Max LP	76.453	99.964	37.783	-15.998	168.904	2.023	6	.089
Avg LP	65.594	81.835	30.931	-10.091	141.279	2.121	6	.078
Max RP	617.296	1732.523	654.832	-985.021	2219.612	0.943	6	.382
Avg RP	1527.716	2188.279	827.092	-496.105	3551.536	1.847	6	.114
Max TP	683.306	1701.829	643.231	-890.623	2257.235	1.062	6	.329
Avg TP	1593.313	2183.411	825.252	-426.006	3612.632	1.931	6	.102
Accuracy	1.611	16.229	6.134	-13.398	16.621	0.263	6	.802

Central Tendency for Right Straight to the Head

	Test	*N*	Mean	*SD*	Std. Error Mean
TRT	Pre	7	0.704	0.177	0.067
	Post	7	0.644	0.155	0.058
CNS	Pre	7	0.426	0.078	0.029
	Post	7	0.364	0.093	0.035
PNS	Pre	7	0.281	0.129	0.049
	Post	7	0.280	0.092	0.035
Max LP	Pre	7	610.080	556.572	210.365
	Post	7	537.253	493.420	186.495
Avg LP	Pre	7	359.597	286.219	108.180
	Post	7	317.689	251.548	95.076
Max RP	Pre	7	4086.434	2404.181	908.695
	Post	7	3868.514	2879.987	1088.533
Avg RP	Pre	7	2142.634	989.002	373.808
	Post	7	1971.804	1072.809	405.484
Max TP	Pre	7	4648.576	2936.377	1109.846
	Post	7	4355.061	3359.091	1269.617
Avg TP	Pre	7	2502.234	1252.908	473.555
	Post	7	2289.497	1301.058	491.754
Accuracy	Pre	7	60.290	21.762	8.225
	Post	7	79.361	32.710	12.363

Table: T-Test Results for Right Straight to the Head

Metric	Paired Differences					*t*	*df*	Sig. (2-tailed)
	Mean	*SD*	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
TRT	.060	.059	.022	.006	.114	2.709	6	.035
CNS	.061	.058	.022	.008	.115	2.809	6	.031
PNS	.001	.084	.032	-.076	.079	0.045	6	.966
Max LP	72.827	117.165	44.284	-35.533	181.187	1.645	6	.151
Avg LP	41.909	66.987	25.319	-20.044	103.861	1.655	6	.149
Max RP	217.920	846.192	319.831	-564.677	1000.517	0.681	6	.521
Avg RP	170.830	410.741	155.245	-209.042	550.702	1.100	6	.313
Max TP	293.514	886.189	334.948	-526.074	1113.102	0.876	6	.415
Avg TP	212.737	445.978	168.564	-199.724	625.198	1.262	6	.254
Accuracy	-19.071	18.748	7.086	-36.410	-1.733	-2.691	6	.036

Central Tendency for Left Kick to the Head

	Test	*N*	Mean	*SD*	Std. Error Mean
TRT	Pre	3	0.930	0.066	0.038
	Post	3	0.907	0.119	0.069
CNS	Pre	3	0.560	0.095	0.055
	Post	3	0.527	0.146	0.084
PNS	Pre	3	0.370	0.035	0.020
	Post	3	0.377	0.064	0.037
Max LP	Pre	3	1044.410	764.936	441.636
	Post	3	1015.207	714.658	412.608
Avg LP	Pre	3	673.880	501.148	289.338
	Post	3	719.103	505.996	292.137
Max RP	Pre	3	1619.330	400.163	231.034
	Post	3	1745.643	99.247	57.300
Avg RP	Pre	3	1024.327	393.256	227.047
	Post	3	1197.120	64.829	37.429
Max TP	Pre	3	2629.457	669.231	386.381
	Post	3	2740.813	828.164	478.141
Avg TP	Pre	3	1698.210	518.588	299.407
	Post	3	1916.220	519.455	299.908
Accuracy	Pre	3	193.143	71.483	41.271
	Post	3	204.610	81.591	47.107

T-Test Results for Left Kick to the Head

Metric	Paired Differences					*t*	*df*	Sig. (2-tailed)
	Mean	*SD*	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
TRT	.023	.078	.045	-.170	.216	0.520	2	.655
CNS	.033	.067	.038	-.132	.199	0.867	2	.477
PNS	-.007	.031	.018	-.083	.069	-0.378	2	.742
Max LP	29.203	114.033	65.837	-254.069	312.476	0.444	2	.701
Avg LP	-45.223	58.757	33.923	-191.184	100.737	-1.333	2	.314
Max RP	-126.313	492.913	284.584	-1350.778	1098.151	-0.444	2	.701
Avg RP	-172.793	342.475	197.728	-1023.549	677.962	-.874	2	.474
Max TP	-111.357	538.073	310.656	-1448.003	1225.290	-0.358	2	.754
Avg TP	-218.010	396.422	228.874	-1202.777	766.757	-.953	2	.441
Accuracy	-11.467	32.719	18.890	-92.745	69.811	-0.607	2	.606

Central Tendency for Left Kick to the Leg

	Test	*N*	Mean	*SD*	Std. Error Mean
TRT	Pre	3	.880	.085	.049
	Post	3	.873	.065	.038
CNS	Pre	3	.620	.036	.021
	Post	3	.550	.089	.051
PNS	Pre	3	.260	.104	.060
	Post	3	.327	.025	.015
Max LP	Pre	3	932.217	517.555	298.811
	Post	3	891.087	525.525	303.412
Avg LP	Pre	3	494.120	281.656	162.614
	Post	3	457.423	278.717	160.917
Max RP	Pre	3	1791.223	242.486	140.000
	Post	3	2474.060	1222.776	705.970
Avg RP	Pre	3	1086.703	41.234	23.806
	Post	3	1480.980	648.502	374.413
Max TP	Pre	3	2472.410	280.878	162.165
	Post	3	3189.610	1137.378	656.665
Avg TP	Pre	3	1580.823	289.561	167.178
	Post	3	1938.400	590.122	340.707
Accuracy	Pre	3	204.337	23.292	13.447
	Post	3	201.583	66.457	38.369

T-Test Results for Left Kick to the Leg

Metric	Paired Differences					*t*	*df*	Sig. (2-tailed)
	Mean	*SD*	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
TRT	.007	.023	.013	-.051	.064	0.500	2	.667
CNS	.070	.095	.055	-.167	.307	1.271	2	.332
PNS	-.067	.112	.065	-.346	.213	-1.027	2	.412
Max LP	41.130	147.674	85.260	-325.713	407.973	0.482	2	.677
Avg LP	36.697	61.318	35.402	-115.626	189.020	1.037	2	.409
Max RP	-682.837	1074.802	620.537	-3352.794	1987.120	-1.100	2	.386
Avg RP	-394.277	684.488	395.189	-2094.638	1306.085	-.998	2	.424
Max TP	-717.200	1052.597	607.717	-3331.996	1897.596	-1.180	2	.359
Avg TP	-357.577	739.942	427.206	-2195.696	1480.542	-.837	2	.491
Accuracy	2.753	46.668	26.944	-113.177	118.683	0.102	2	.928

Central Tendency for Left Kick to the Body

	Test	*N*	Mean	*SD*	Std. Error Mean
TRT	Pre	2	.895	.092	.065
	Post	2	.875	.120	.085
CNS	Pre	2	.440	.226	.160
	Post	2	.515	.106	.075
PNS	Pre	2	.455	.134	.095
	Post	2	.365	.021	.015
Max LP	Pre	2	1091.815	793.084	560.795
	Post	2	1256.410	955.485	675.630
Avg LP	Pre	2	687.435	499.380	353.115
	Post	2	823.095	607.949	429.885
Max RP	Pre	2	686.515	145.671	103.005
	Post	2	550.040	91.203	64.490
Avg RP	Pre	2	329.770	31.381	22.190
	Post	2	277.730	26.743	18.910
Max TP	Pre	2	1648.095	877.696	620.625
	Post	2	1667.375	965.123	682.445
Avg TP	Pre	2	1017.205	467.999	330.925
	Post	2	1100.825	581.206	410.975
Accuracy	Pre	2	143.755	8.195	5.795
	Post	2	122.950	63.880	45.170

T-Test Results for Left Kick to the Body

Metric	Paired Differences					t	df	Sig. (2-tailed)
	Mean	*SD*	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
TRT	.020	.028	.020	-.234	.274	1.000	1	.500
CNS	-.075	.120	.085	-1.155	1.005	-0.882	1	.540
PNS	.090	.156	.110	-1.308	1.488	0.818	1	.563
Max LP	-164.595	162.401	114.835	-1623.712	1294.522	-1.433	1	.388
Avg LP	-135.660	108.569	76.770	-1111.115	839.795	-1.767	1	.328
Max RP	136.475	54.468	38.515	-352.904	625.854	3.543	1	.175
Avg RP	52.040	4.639	3.280	10.364	93.716	15.866	1	.040
Max TP	-19.280	87.427	61.820	-804.778	766.218	-0.312	1	.808
Avg TP	-83.620	113.208	80.050	-1100.752	933.512	-1.045	1	.486
Accuracy	20.805	72.075	50.965	-626.767	668.377	0.408	1	.753

Central Tendency for Right Kick to the Head

	Test	*N*	Mean	*SD*	Std. Error Mean
TRT	Pre	3	.940	.113	.065
	Post	3	.893	.092	.053
CNS	Pre	3	.760	.050	.029
	Post	3	.597	.144	.083
PNS	Pre	3	.183	.078	.045
	Post	3	.300	.234	.135
Max LP	Pre	3	917.460	497.762	287.383
	Post	3	964.370	563.584	325.385
Avg LP	Pre	3	600.933	355.441	205.214
	Post	3	648.570	413.031	238.464
Max RP	Pre	3	8001.190	2582.254	1490.865
	Post	3	8964.403	3909.428	2257.109
Avg RP	Pre	3	5133.327	1406.954	812.306
	Post	3	5522.783	2146.520	1239.294
Max TP	Pre	3	8740.907	2501.395	1444.181
	Post	3	9776.523	3900.394	2251.893
Avg TP	Pre	3	5734.260	1227.830	708.888
	Post	3	6171.363	2099.429	1212.106
Accuracy	Pre	3	180.643	41.158	23.763
	Post	3	172.387	39.387	22.740

T-Test Results for Right Kick to the Head

Metric	Paired Differences					*t*	*df*	Sig. (2-tailed)
	Mean	*SD*	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
TRT	.047	.021	.012	-.005	.098	3.883	2	.060
CNS	.163	.189	.109	-.307	.634	1.494	2	.274
PNS	-.117	.159	.092	-.513	.279	-1.267	2	.333
Max LP	-46.910	77.105	44.517	-238.449	144.629	-1.054	2	.403
Avg LP	-47.637	73.119	42.215	-229.275	134.002	-1.128	2	.376
Max RP	-963.213	1338.981	773.061	-4289.427	2363.000	-1.246	2	.339
Avg RP	-389.457	916.806	529.318	-2666.929	1888.016	-.736	2	.538
Max TP	-1035.617	1440.223	831.513	-4613.330	2542.096	-1.245	2	.339
Avg TP	-437.103	974.668	562.725	-2858.313	1984.106	-.777	2	.519
Accuracy	8.257	3.708	2.141	-.955	17.468	3.857	2	.061

Central Tendency for Right Kick to the Leg

	Test	*N*	Mean	*SD*	Std. Error Mean
TRT	Pre	3	.977	.127	.073
	Post	3	.863	.137	.079
CNS	Pre	3	.780	.072	.042
	Post	3	.543	.139	.080
PNS	Pre	3	.193	.070	.041
	Post	3	.320	.260	.150
Max LP	Pre	3	1226.397	694.558	401.003
	Post	3	1215.630	599.364	346.043
Avg LP	Pre	3	636.820	346.128	199.837
	Post	3	610.603	283.545	163.705
Max RP	Pre	3	5736.603	2343.611	1353.084
	Post	3	6370.953	2412.407	1392.804
Avg RP	Pre	3	3419.997	1152.296	665.278
	Post	3	3539.383	1190.002	687.048
Max TP	Pre	3	6752.200	2475.285	1429.106
	Post	3	7393.227	2388.140	1378.793
Avg TP	Pre	3	4056.813	1102.730	636.662
	Post	3	4149.990	1046.785	604.361
Accuracy	Pre	3	222.507	28.868	16.667
	Post	3	255.003	52.048	30.050

T-Test Results for Right Kick to the Leg

Metric	Paired Differences					*t*	*df*	Sig. (2-tailed)
	Mean	*SD*	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
TRT	.113	.025	.015	.051	.176	7.800	2	.016
CNS	.237	.211	.122	-.287	.760	1.945	2	.191
PNS	-.127	.204	.118	-.634	.381	-1.074	2	.395
Max LP	10.767	158.058	91.255	-381.870	403.404	0.118	2	.917
Avg LP	26.217	77.694	44.856	-166.785	219.218	0.584	2	.618
Max RP	-634.350	840.830	485.453	-2723.087	1454.387	-1.307	2	.321
Avg RP	-119.387	567.456	327.621	-1529.027	1290.253	-.364	2	.750
Max TP	-641.027	891.051	514.449	-2854.521	1572.468	-1.246	2	.339
Avg TP	-93.177	610.556	352.505	-1609.881	1423.528	-.264	2	.816
Accuracy	-32.497	43.563	25.151	-140.714	75.721	-1.292	2	.326

Central Tendency for Right Kick to the Body

	Test	*N*	Mean	*SD*	Std. Error Mean
TRT	Pre	3	.937	.099	.057
	Post	3	.890	.106	.061
CNS	Pre	3	.760	.046	.026
	Post	3	.497	.153	.088
PNS	Pre	3	.177	.067	.038
	Post	3	.390	.221	.127
Max LP	Pre	3	1359.327	510.227	294.579
	Post	3	1401.953	530.880	306.504
Avg LP	Pre	3	800.460	310.349	179.180
	Post	3	852.247	309.831	178.881
Max RP	Pre	3	1785.507	543.187	313.609
	Post	3	659.967	207.929	120.048
Avg RP	Pre	3	1028.323	302.882	174.869
	Post	3	394.387	109.045	62.957
Max TP	Pre	3	2938.377	313.451	180.971
	Post	3	1926.440	436.354	251.929
Avg TP	Pre	3	1828.783	24.702	14.262
	Post	3	1246.627	221.190	127.704
Accuracy	Pre	3	174.750	14.613	8.437
	Post	3	222.830	22.913	13.229

T-Test Results for Right Kick to the Body

Metric	Paired Differences					*t*	*df*	Sig. (2-tailed)
	Mean	*SD*	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
TRT	.047	.031	.018	-.029	.123	2.646	2	.118
CNS	.263	.199	.115	-.230	.757	2.297	2	.148
PNS	-.213	.178	.103	-.655	.228	-2.078	2	.173
Max LP	-42.627	21.679	12.517	-96.481	11.228	-3.406	2	.076
Avg LP	-51.787	73.505	42.438	-234.383	130.810	-1.220	2	.347
Max RP	1125.540	337.756	195.004	286.507	1964.573	5.772	2	.029
Avg RP	633.937	203.886	117.714	127.456	1140.418	5.385	2	.033
Max TP	1011.937	329.682	190.342	192.962	1830.911	5.316	2	.034
Avg TP	582.157	225.859	130.400	21.093	1143.221	4.464	2	.047
Accuracy	-48.080	37.077	21.406	-140.183	44.023	-2.246	2	.154

Appendix F: Tables for Individual Participants

Central Tendency for Participant 1

Metric (zscores)	Test	*N*	Mean	*SD*	Std. Error Mean
TRT	Pre	6	0.530	0.085	0.035
	Post	6	0.463	0.061	0.025
CNS	Pre	6	0.345	0.063	0.026
	Post	6	0.237	0.030	0.012
PNS	Pre	6	0.183	0.106	0.043
	Post	6	0.227	0.050	0.020
Max LP	Pre	6	199.812	65.642	26.798
	Post	6	10901.132	16864.272	6884.810
Avg LP	Pre	6	145.467	55.565	22.684
	Post	6	4229.785	6444.609	2631.001
Max RP	Pre	6	1980.358	2605.883	1063.847
	Post	6	5150.250	4972.733	2030.110
Avg RP	Pre	6	1866.550	3173.667	1295.644
	Post	6	2367.378	1894.822	773.558
Max TP	Pre	6	2144.227	2606.340	1064.034
	Post	6	16024.335	21583.778	8811.540
Avg TP	Pre	6	2012.020	3208.973	1310.058
	Post	6	6597.162	8037.340	3281.230
Accuracy	Pre	6	53.923	20.548	8.389
	Post	6	79.940	30.675	12.523

T-Test Results for Participant 1

Metric	Paired Differences					t	df	Sig. (2-tailed)
	Mean	*SD*	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
TRT	.067	.065	.027	-.002	.135	2.512	5	.054
CNS	.108	.069	.028	.036	.181	3.856	5	.012
PNS	-.043	.114	.047	-.163	.077	-0.927	5	.396
Max LP	-10701.320	16826.266	6869.295	-28359.404	6956.764	-1.558	5	.180
Avg LP	-4084.318	6436.212	2627.573	-10838.709	2670.072	-1.554	5	.181
Max RP	-3169.892	6025.943	2460.081	-9493.731	3153.948	-1.289	5	.254
Avg RP	-500.828	3379.042	1379.488	-4046.915	3045.259	-.363	5	.731
Max TP	-13880.108	22831.531	9320.934	-37840.331	10080.115	-1.489	5	.197
Avg TP	-4585.142	9477.827	3869.307	-14531.511	5361.228	-1.185	5	.289
Accuracy	-26.017	17.438	7.119	-44.317	-7.717	-3.655	5	.015

Central Tendency for Participant 2

Metric (zscores)	**Test**	***N***	**Mean**	***SD***	**Std. Error Mean**
TRT	Pre	12	.738	.137	.040
	Post	12	.721	.120	.035
CNS	Pre	12	.518	.166	.048
	Post	12	.461	.136	.039
PNS	Pre	12	.220	.151	.043
	Post	12	.260	.091	.026
Max LP	Pre	12	379.547	160.420	46.309
	Post	12	364.681	180.919	52.227
Avg LP	Pre	12	242.023	88.873	25.655
	Post	12	243.176	106.959	30.877
Max RP	Pre	12	2372.250	2322.774	670.527
	Post	12	2196.050	2726.152	786.972
Avg RP	Pre	12	1658.783	1764.360	509.327
	Post	12	1392.992	1688.033	487.293
Max TP	Pre	12	2644.677	2309.774	666.774
	Post	12	2474.170	2717.905	784.592
Avg TP	Pre	12	1900.809	1765.807	509.745
	Post	12	1636.168	1688.965	487.562
Accuracy	Pre	12	131.283	75.038	21.662
	Post	12	144.253	85.507	24.684

T-Test Results for Participant 2

Metric	Paired Differences					*t*	*df*	Sig. (2-tailed)
	Mean	*SD*	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
TRT	.018	.048	.014	-.013	.048	1.256	11	.235
CNS	.057	.103	.030	-.008	.123	1.931	11	.080
PNS	-.040	.110	.032	-.110	.030	-1.260	11	.234
Max LP	14.866	70.504	20.353	-29.930	59.662	0.730	11	.480
Avg LP	-1.153	38.411	11.088	-25.558	23.253	-0.104	11	.919
Max RP	176.200	1065.913	307.703	-501.049	853.449	0.573	11	.578
Avg RP	265.792	824.609	238.044	-258.140	789.723	1.117	11	.288
Max TP	170.507	1048.173	302.582	-495.471	836.484	0.564	11	.584
Avg TP	264.641	813.334	234.789	-252.127	781.409	1.127	11	.284
Accuracy	-12.970	28.816	8.319	-31.279	5.339	-1.559	11	.147

Central Tendency for Participant 3

Metric (zscores)	Test	*N*	Mean	*SD*	Std. Error Mean
TRT	Pre	5	1.148	.154	.069
	Post	5	1.044	.200	.090
CNS	Pre	5	0.764	.311	.139
	Post	5	0.654	.228	.102
PNS	Pre	5	0.388	.263	.118
	Post	5	0.388	.215	.096
Max LP	Pre	5	372.482	173.043	77.387
	Post	5	294.642	110.163	49.266
Avg LP	Pre	5	251.036	108.019	48.308
	Post	5	209.404	88.493	39.575
Max RP	Pre	5	2855.088	3081.517	1378.096
	Post	5	3158.024	3872.602	1731.880
Avg RP	Pre	5	1590.866	2088.956	934.210
	Post	5	1888.612	2615.655	1169.756
Max TP	Pre	5	3168.066	3038.182	1358.717
	Post	5	3399.382	3863.006	1727.589
Avg TP	Pre	5	1841.904	2090.523	934.910
	Post	5	2098.020	2641.990	1181.534
Accuracy	Pre	5	61.688	37.531	16.784
	Post	5	64.650	10.048	4.494

T-Test Results for Participant 3

Metric	Paired Differences					t	df	Sig. (2-tailed)
	Mean	*SD*	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
TRT	.104	.090	.040	-.008	.216	2.571	4	.062
CNS	.110	.254	.114	-.206	.426	0.967	4	.388
PNS	.000	.190	.085	-.236	.236	0.000	4	1.000
Max LP	77.840	68.660	30.706	-7.413	163.093	2.535	4	.064
Avg LP	41.632	36.635	16.384	-3.857	87.121	2.541	4	.064
Max RP	-302.936	980.427	438.460	-1520.297	914.425	-0.691	4	.528
Avg RP	-297.746	546.768	244.522	-976.648	381.156	-1.218	4	.290
Max TP	-231.316	997.473	446.083	-1469.842	1007.210	-0.519	4	.631
Avg TP	-256.116	570.130	254.970	-964.026	451.794	-1.004	4	.372
Accuracy	-2.962	29.398	13.147	-39.464	33.540	-0.225	4	.833

Central Tendency for Participant 4

Metric (zscores)	**Test**	***N***	**Mean**	***SD***	**Std. Error Mean**
TRT	Pre	11	.781	.129	.039
	Post	11	.745	.090	.027
CNS	Pre	11	.532	.168	.051
	Post	11	.479	.085	.026
PNS	Pre	11	.250	.111	.033
	Post	11	.265	.083	.025
Max LP	Pre	11	1050.905	350.142	105.572
	Post	11	963.700	358.460	108.080
Avg LP	Pre	11	637.337	183.519	55.333
	Post	11	610.917	185.838	56.032
Max RP	Pre	11	3313.508	3572.369	1077.110
	Post	11	3115.967	3940.590	1188.133
Avg RP	Pre	11	2061.255	2328.730	702.139
	Post	11	1943.825	2460.350	741.824
Max TP	Pre	11	4206.982	3541.391	1067.770
	Post	11	3976.999	3943.830	1189.110
Avg TP	Pre	11	2698.593	2321.113	699.842
	Post	11	2554.738	2455.870	740.473
Accuracy	Pre	11	108.879	68.282	20.588
	Post	11	130.071	95.519	28.800

T-Test Results for Participant 4

Metric	Paired Differences					t	df	Sig. (2-tailed)
	Mean	*SD*	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
TRT	.035	.058	.018	-.004	.075	2.020	10	.071
CNS	.053	.121	.036	-.028	.134	1.447	10	.178
PNS	-.015	.089	.027	-.075	.044	-0.575	10	.578
Max LP	87.205	146.759	44.249	-11.389	185.798	1.971	10	.077
Avg LP	26.420	117.647	35.472	-52.616	105.456	0.745	10	.474
Max RP	197.541	1135.435	342.347	-565.255	960.337	0.577	10	.577
Avg RP	117.431	702.790	211.899	-354.710	589.572	.554	10	.592
Max TP	229.983	1231.629	371.350	-597.437	1057.402	0.619	10	.550
Avg TP	143.855	772.672	232.969	-375.233	662.942	.617	10	.551
Accuracy	-21.192	33.553	10.116	-43.733	1.349	-2.095	10	.063

Central Tendency for Participant 5

Metric (zscores)	**Test**	***N***	**Mean**	***SD***	**Std. Error Mean**
TRT	Pre	12	.889	.156	.045
	Post	12	.858	.157	.045
CNS	Pre	12	.566	.186	.054
	Post	12	.446	.135	.039
PNS	Pre	12	.325	.086	.025
	Post	12	.413	.141	.041
Max LP	Pre	12	1383.897	315.240	91.002
	Post	12	1393.318	377.231	108.897
Avg LP	Pre	12	884.832	224.733	64.875
	Post	12	883.694	285.557	82.433
Max RP	Pre	12	3397.565	3624.022	1046.165
	Post	12	3702.542	4093.157	1181.593
Avg RP	Pre	12	2023.241	2281.910	658.731
	Post	12	2103.009	2461.920	710.695
Max TP	Pre	12	4695.473	3709.028	1070.704
	Post	12	5006.048	4093.752	1181.765
Avg TP	Pre	12	2908.072	2320.362	669.831
	Post	12	2986.705	2445.450	705.941
Accuracy	Pre	12	125.984	80.017	23.099
	Post	12	119.083	75.539	21.806

T-Test Results for Participant 5

Metric	Paired Differences					t	df	Sig. (2-tailed)
	Mean	*SD*	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
TRT	.031	.062	.018	-.008	.070	1.731	11	.111
CNS	.120	.196	.057	-.005	.245	2.116	11	.058
PNS	-.088	.161	.047	-.190	.015	-1.879	11	.087
Max LP	-9.422	157.151	45.366	-109.271	90.428	-0.208	11	.839
Avg LP	1.138	137.532	39.702	-86.246	88.521	0.029	11	.978
Max RP	-304.977	770.041	222.292	-794.237	184.284	-1.372	11	.197
Avg RP	-79.768	407.142	117.532	-338.454	178.917	-.679	11	.511
Max TP	-310.576	718.248	207.340	-766.929	145.777	-1.498	11	.162
Avg TP	-78.633	429.331	123.937	-351.417	194.151	-.634	11	.539
Accuracy	6.902	25.880	7.471	-9.542	23.345	0.924	11	.375

Central Tendency for Participant 6

Metric (zscores)	**Test**	***N***	**Mean**	***SD***	**Std. Error Mean**
TRT	Pre	6	.657	.114	.047
	Post	6	.628	.106	.043
CNS	Pre	6	.408	.085	.035
	Post	6	.305	.068	.028
PNS	Pre	6	.250	.071	.029
	Post	6	.325	.121	.049
Max LP	Pre	6	156.740	75.621	30.872
	Post	6	123.455	52.573	21.463
Avg LP	Pre	6	114.965	53.515	21.847
	Post	6	97.203	48.523	19.809
Max RP	Pre	6	875.608	1058.307	432.052
	Post	6	744.380	795.655	324.825
Avg RP	Pre	6	704.395	1022.878	417.588
	Post	6	571.132	715.131	291.951
Max TP	Pre	6	1002.447	1015.823	414.708
	Post	6	845.090	754.751	308.126
Avg TP	Pre	6	819.360	1005.685	410.569
	Post	6	668.337	687.910	280.838
Accuracy	Pre	6	65.650	46.226	18.872
	Post	6	70.347	33.305	13.597

T-Test Results for Participant 6

Metric	Paired Differences					*t*	*df*	Sig. (2-tailed)
	Mean	*SD*	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
TRT	.028	.035	.014	-.009	.066	1.958	5	.108
CNS	.103	.072	.029	.028	.179	3.528	5	.017
PNS	-.075	.100	.041	-.179	.029	-1.845	5	.124
Max LP	33.285	33.941	13.857	-2.334	68.904	2.402	5	.061
Avg LP	17.762	13.869	5.662	3.207	32.317	3.137	5	.026
Max RP	131.228	466.114	190.290	-357.929	620.385	0.690	5	.521
Avg RP	133.263	373.732	152.575	-258.944	525.471	.873	5	.422
Max TP	157.357	472.344	192.834	-338.338	653.052	0.816	5	.452
Avg TP	151.023	383.191	156.437	-251.111	553.157	.965	5	.379
Accuracy	-4.697	27.189	11.100	-33.230	23.837	-0.423	5	.690

Central Tendency for Participant 7

Metric (zscores)	Test	*N*	Mean	*SD*	Std. Error Mean
TRT	Pre	6	.963	.045	.019
	Post	6	.815	.059	.024
CNS	Pre	6	.772	.228	.093
	Post	6	.490	.089	.036
PNS	Pre	6	.195	.238	.097
	Post	6	.327	.087	.036
Max LP	Pre	6	303.272	41.670	17.012
	Post	6	317.325	106.874	43.631
Avg LP	Pre	6	216.505	42.145	17.206
	Post	6	210.468	78.942	32.228
Max RP	Pre	6	3448.818	4105.165	1675.927
	Post	6	3288.382	3562.615	1454.432
Avg RP	Pre	6	2258.350	3153.128	1287.259
	Post	6	1715.958	1814.872	740.919
Max TP	Pre	6	3678.388	4105.123	1675.909
	Post	6	3526.093	3550.791	1449.604
Avg TP	Pre	6	2474.857	3170.425	1294.321
	Post	6	1926.428	1831.204	747.586
Accuracy	Pre	6	59.182	23.448	9.573
	Post	6	45.432	17.209	7.026

T-Test Results for Participant 7

Metric	Paired Differences					t	df	Sig. (2-tailed)
	Mean	*SD*	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
TRT	.148	.045	.019	.101	.196	8.012	5	.000
CNS	.282	.182	.074	.090	.473	3.783	5	.013
PNS	-.132	.207	.085	-.349	.086	-1.556	5	.180
Max LP	-14.053	82.949	33.864	-101.103	72.997	-0.415	5	.695
Avg LP	6.037	43.971	17.951	-40.108	52.182	0.336	5	.750
Max RP	160.437	693.929	283.295	-567.797	888.670	0.566	5	.596
Avg RP	542.392	1426.967	582.557	-955.118	2039.902	.931	5	.395
Max TP	152.295	719.100	293.571	-602.354	906.944	0.519	5	.626
Avg TP	548.428	1452.785	593.097	-976.176	2073.032	.925	5	.398
Accuracy	13.750	12.354	5.044	.785	26.715	2.726	5	.041