2021

The Relationship Between Rapid Weight Loss and Physical Performance in Combat Sports

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THE RELATIONSHIP BETWEEN RAPID WEIGHT LOSS AND PHYSICAL PERFORMANCE IN COMBAT SPORTS

by

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A thesis submitted in partial fulfillment of the requirements
for the Honors in the Major Program in Sport and Exercise Science
in the College of Health Professions and Sciences
and in the Burnett Honors College
at the University of Central Florida
Orlando, Florida

Spring Term 2021

Thesis Chair: Anna Valdes, Ed.D.

ABSTRACT

The purpose of this study is to determine if there is a relationship between rapid weight loss and physical performance in combat sports athletes. Inclusion criteria was rapid weight loss and physical performance effects among combat sports researched in the last 20 years. Phrases as well as key words were searched using multiple databases. The key words included mixed martial arts (MMA), judo, wrestling, taekwondo, boxing, studies which looked at multiple disciplines at once, and unspecified disciplines. Results of the literature review indicate that there are negative effects on performance due to rapid weight loss and dehydration in combat sports. Appendix I summarizes the data found. However, other literature has suggested no physical performance effects following a period of rapid weight loss. Determination at what percentage of body mass loss unequivocally affects physical performance measures and the threshold in which a certain athlete is likely to experience these effects is key. Factors which seem to influence the magnitude of measured performance effects include the length of recovery time following the period of rapid weight loss, magnitude of body mass lost, as well as methods used to achieve weight loss. The results of this study may help provide insight into areas of research which are lacking data on this subject and may also provide helpful guidelines for combat sport athletes and trainers alike.

DEDICATIONS

This research is dedicated to a host of individuals including my mother Bridget for the continued love and support throughout my life and through all the difficult circumstances which we have faced together. My training partners and coaches (Julien Williams, Leo West) at Fusion X-Cel Performance gym for the amazing environment in which to train which cultivated my interest in trying to give back in my own way to the gym and community through this research. To my friend Jason for introducing me to jiu-jitsu and the lessons taught along the way I am grateful, and to my immediate family and other close friends, I appreciate the support. None of this would have been possible without these individuals.

ACKNOWLEDGEMENTS

I would like to acknowledge the help and mentorship of committee members Dr. Anna Valdes and Dr. Thomas Fisher for their help and guidance throughout the process of this research. The patience, the encouragement, and the wealth of amazing feedback that I received throughout the writing will never go unappreciated nor will it ever be forgotten. I would also like to acknowledge the help and resources provided by the Burnett Honor's College as well as the staff who work directly with the students within the Honor's Undergraduate Research Office.

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INTRODUCTION

Combat sports are defined as a class of contact sports in which two individuals engage in one-on-one combat. Rules for scoring points and winning differ depending on the type of combat sport. “Combat sports” therefore is an umbrella term that includes but is not limited to sports and disciplines such as Judo, Brazilian Jiu-Jitsu, kickboxing, boxing, wrestling, mixed martial arts (MMA), Taekwondo, and Karate (Barley, Chapman, & Abbiss, 2019). Divisions of competition are based on weight classes. Weight classes are implemented to match athletes against other athletes close to their weight and size. Doing so provides a more equitable level of competition, while reducing potential injuries that may be caused by differences in strength due to a large difference in body mass (Pettersson, Ekström, & Berg, 2013). The existence of these weight classes/divisions does give rise to the practice of weight cutting. Weight cutting or rapid weight loss (RWL) is a form of short-term weight manipulation (Conor and Egan, 2019). By weight cutting, a larger athlete could reduce weight to participate at the high end of a lower weight class. By doing so, that said competitor could gain a competitive advantage. In the process of RWL, the athlete loses a certain percentage of their body mass in a short period of time before weighing in. Once the athlete has weighed in for the competition at that lighter weight class, they typically regain the weight they lost in between the time of weigh in and the time of the competition. This time varies between sports and organizations.

One reason behind RWL, according to Barley, Chapman, and Abbiss (2019) is for the athlete to gain a competitive advantage against a smaller opponent. Depending on the rehydration protocol utilized by the athlete, some athletes may or may not be able to regain the weight they lost *(*Alves et al. 2018). This could negate the competitive advantage the athlete was seeking to gain. According to Connor and Egan (2019), RWL refers to a variety of methods used by combat sports athletes, usually within the final week of the competition, to reduce body mass by a range anywhere from 2% to 10%. Given that most of the weight athletes typically lose is within the final week before a fight, the quick loss in body mass usually results from dehydration. The methods used to dehydrate include water loading, saunas, increased exercise, fluid restriction, and/or extreme methods such as vomiting, diuretics, and spitting (Artioli, Gulano et al,. 2010; Artioli, Scagliusi et al., 2010). Literature on the prevalence of rapid weight loss among combat sports athletes suggest that a majority of athletes, across multiple combat sports and disciplines, engage in some form of weight cutting to compete, regardless of age, gender, experience level or level of competition (do Nascimento et al., 2020; Connor & Egan, 2019; Britto et al., 2012; da Silva et al., 2016; Hillier et al. 2019; Artioli, Gulano, et al., 2010). A position statement by McDermott et al. (2017) and the National Athletic Trainer's Association (NATA), determined that levels of hypohydration (a deficit of body water that is caused by acute or chronic dehydration) can be defined from both a clinical and athletic perspective. The levels occur on a continuum. From a clinical perspective, mild dehydration is defined as being between 1 and 5% of body mass lost. Moderate dehydration is between 5 to 10% of body mass lost, and severe hypohydration is a loss greater than 10% body mass. From an athletic perspective, McDermott et al. (2017) defined mild to moderate hypohydration as being between 2 and 5% body mass lost. A loss greater than 5% body mass is severe. In the same position statement, McDermott et al. (2017) and NATA recommended to the individual that fluids should be easily accessible throughout physical activity (before, during, and after). Immediately following the activity (within 2 hours of ceasing the activity) athletes should eat and drink to replace fluids, electrolytes, carbohydrates, and proteins broken down and lost during physical activity. If precautions are not taken, when athletes reach certain levels of hypohydration, some detrimental physiological effects can occur. Thermoregulatory processes can become affected with hypohydration levels greater than 1%. Cardiovascular strain also increases during exercise if hypohydration levels reach a certain threshold (McDermott et al., 2017). Given that according to Conor and Egan (2019), combat sports athletes lose anywhere from between 2 to 10% of their body weight using rapid weight loss techniques, this would also indicate that in accordance to NATA and McDermott et al. (2017), athletes from both a clinical and athletic perspective also experience hypohydration/dehydration ranging from mild to severe during these periods of RWL.

The practice of losing weight to compete is not limited to one sport. It is found across the combat sports community. Artioli, Gulano et al. (2010) had found in a survey of 822 Judo athletes over a 2 year period (2006-2008) that between 86 and 89% of participants had lost weight to compete or engaged in some form of weight loss behavior. Hillier et al. (2019) in a survey of 314 MMA athletes that 97.2% of men surveyed (n=287) and 100% of the women surveyed (n=27) had lost weight to compete and/or engaged in some form of RWL.

There is evidence to suggest that hypohydration not only affects health but could interfere with physical performance measures such as aerobic performance (Cheuvront & Kenefick, 2014), muscular strength (Judelson et al. 2007, Hayes & Morse, 2010, Savoie et al., 2015), anaerobic performance and power (Judelson et al., 2007, Jones et al., 2008, Kraft et al., 2011, Savoie et al., 2015) and muscular endurance (Périard et al., 2012, Savoie et al., 2015). When examined from a more sport-specific standpoint, the negative effect rapid weight loss has on sport specific performance tests that mimic the demands of certain combat sports have also been measured (Hall et al., 2001, Barley, Iredale et al., 2018, Alves et al., 2018, Koral & Dosseville, 2009).

Given the numbers found in the research such as a near 90% prevalence within Judo (Artioli, Gulano et al., 2010) and a virtually 100% prevalence within MMA (Conor and Egan, 2019; Hillier et al., 2019), the purpose of this research is to review the available literature on the effects of rapid weight loss on physical performance measures within combat sports. Specifically, the effects on strength, aerobic performance measurements, anaerobic performance measurements, power output, muscular endurance and other sport specific performance tests following a period of rapid weight loss.

LITERATURE REVIEW

Prevalence of Rapid Weight Loss in Combat Sports Athletes

The prevalence of RWL within the combat sports community will be discussed in this section. As will be seen, a vast majority of athletes across multiple disciplines have utilized a variety of methods to make weight. Studies which examine the prevalence as well as methods of assessing the prevalence of RWL within combat sports will be discussed in this section. Appendix B will provide a table which summarizes the findings of this section.

Rapid Weight Loss Questionnaire (RWLQ)

The rapid weight loss questionnaire (RWLQ) was developed by Artioli, Scagliusi, et al. (2010) to initially evaluate the weight loss behaviors of judo athletes. It has been adapted for use in several studies examining the prevalence and methods of rapid weight loss in other combat sports. The questions developed for the RWLQ were based mainly on previously developed questionnaires from prior studies done by other researchers which evaluated weight loss patterns among wrestlers. For the study conducted by Artioli, Scagliusi, et al. (2010), the questions developed in the RWLQ were adapted to Judo athletes using terminology specifically from judo. The RWLQ includes questions regarding the athlete's history with weight and diet, personal information, competitive level, and rapid weight loss behaviors. Each individual question has a qualitative value associated with it. At the conclusion of the RWLQ, a total score is obtained which is reflects the type of strategy that athlete uses to cut weight. A higher score is associated with a more aggressive strategy for cutting weight and weight management. A lower score indicates a more conservative weight management strategy. The English version of the RWLQ developed in the study is cited in Appendix A.

Rapid Weight Loss Prevalence in Judo

Artioli, Gulano, et al. (2010) used the RWLQ in their study of Judo of 822 athletes (607 males and 215 females; age = 19.3 ± 5.3 years, weight = 70 ± 7.5 kg, height = 170.6 ± 9.8 cm); to examine RWL tendencies among the community for a two-year period (2006-2008). Results indicated that when heavyweight athletes were included, 86% of the sample population had lost weight to compete. When heavyweights were excluded from the results, 89% of the athletes participated in rapid weight loss. The range of weight lost was 2-5% of body weight. A statistically significant number of athletes lost between 5-10% of body weight (total combined 43.6% of surveyed athletes). Athletes were found to cut weight up to five times per year, but a significant portion of athletes surveyed also cut weight up to ten times per year. Most (66.9%) of the athletes surveyed started to cut weight between the ages of 12 to 16 years old. Common methodologies reported by the athletes to cut weight included using a combination of methods to achieve rapid weight loss. This included gradual dieting, skipping meals, fasting, restricting fluids, increased exercise, heated training rooms, saunas, training in rubber or plastic suits, and spitting. More extreme methods were also used such as laxatives, diuretics, diet pills, and vomiting at a lower frequency.

A more recent survey in a separate study of 186 junior level Judo athletes (age: 13.31 +/- .6 years) all competing at the 2011 Under-15 Brazilian National Judo Championships used a version of the RWLQ (do Nascimento et al., 2020). Athletes were divided into two groups. Novice (less than two years' experience. n=47) and experienced (greater than two years' experience. n=139). Results indicated that regardless of experience, approximately 77% of all athletes surveyed had practiced some form of weight loss. The median age of beginning the practice was 12 years old. The athletes both in the experienced and novice group reported a loss of about 1 kg during the week of the championship. These athletes reported a combination of methods used in order to lose the required weight. The most common methods were increased exercise, training in rubber or plastic suits, heated training rooms, spitting, and restriction of fluids.

Rapid Weight Loss Prevalence in Multiple Disciplines

Brito et al. (2012) examined a population of 580 athletes from jiu-jitsu, judo, taekwondo, and karate all from the state of Minas Gerais, Brazil. Jiu-jitsu athletes were found to reduce their body mass levels later in life when compared to the striking sports (taekwondo and karate) which tended to begin to cut weight early on during adolescence. Of the surveyed population, over 60% of athletes reported rapid weight loss via increased energy expenditure and found a total of 63.1% of the athletes actually lose weight in the period leading up to a competition.

Rapid Weight Loss Prevalence in MMA

Connor and Egan (2019) examined the self-reported weight loss behaviors of MMA athletes in Ireland. Using a version of the RWLQ, a small sample size of 30 male athletes around Dublin (15 professional and 15 amateur) were asked to fill out anonymous questionnaire online. Of the 30 athletes surveyed, only one athlete reported not having lost weight. Almost all (97%) of the athletes surveyed had lost weight to compete. The average amount of weight lost among the athletes was 7.9% (+/- 3.1%). The most common methodologies used as were recorded by reported frequencies by the athletes of "always" or "sometimes" when cutting weight were water loading (90%), hot salt water baths (76%), and 24 hours of fasting (55%).

A study done with a larger sample size of 314 participants conducted by Hillier et al. (2019) examined the magnitude and prevalence of rapid weight loss in mixed martial arts athletes along with the common methods used by the athletes to cut weight. A version of the RWLQ was used to obtain the data that included both males (n=287) and females (n=27) as well as distinctions made between professionals and amateurs. Results indicated that 97.2% of the men and 100% of the women surveyed underwent some form of rapid weight loss in order to compete with differing magnitudes of body mass lost between professional and amateur level competitors both the week of the competition (men: 5.9% vs. 4.2%; women: 5.0% vs. 2.1% of body weight) and in males, the 24 hour prior to competition (3.7% for professionals vs. 2.5% for amateurs of body weight lost).

Rapid Weight Loss Prevalence in Taekwondo

da Silva Santos et al. (2016) studied the prevalence of rapid weight loss among taekwondo athletes of varying skill levels from both a regional/state level and national/international level. A total of 116 athletes were surveyed (72 males, 44 women). Out of the 72 men surveyed (31 of whom were regional/state level competitors, 41 of whom were national/international levels competitors) 77.4% of the regional/state level competitors and 75.6% of the national/international level competitors had reported that they had lost weight to compete. Out of the 44 women surveyed (9 of whom were regional/state level competitors and 35 of whom were national/international level competitors), 88.9% of the regional/state level competitors and 88.6% of the national/international level competitors reported that they have lost weight to compete. The average reported weight loss was approximately 3%.

Rapid Weight Loss Prevalence in Kickboxing

Dugonjić et al. (2019) looked at the prevalence, magnitude, and methodologies of RWL among elite level kickboxers from eight European countries. The Kickboxers, 61 males, completed a version of the RWLQ (24.2 ± 4.6 years, weight = 73.9 ± 12.8 kg, and height = 179.2 ± 7.9 cm). All 61 athletes reported they had engaged in rapid weight loss measures to compete before (100%). Most (81.2%) participants reported weight loss between 0 to 5% of their body mass usually for a competition. Almost 30% of the athletes reported that they had cut 10% or more sometime during their kickboxing career. The average number of days athletes reported losing or reducing body mass was between 7 to 15 days out from competition. 34.4% of the athletes began cutting weight for competition before the age of 17.

Artioli, Gulano, et al. (2010) surveyed a population of 822 athletes in judo and found, excluding heavyweight athletes, 89% of athletes had reported losing weight to compete before a competition. Over 60% of the athletes surveyed by Brito et al. (2012) (n=580) reported they had lost weight before a competition to compete. The prevalence reported by Hillier et al. (2019) in mixed martial artists reported that 97.2% of men surveyed and 100% of the women surveyed had participated in a form of rapid weight loss. The study had a similarly high subject population of 314. These studies also used a version of the previously validated RWLQ developed by Artioli, Scagliusi, et al. (2010). Given the reliability and validity of the test used by the researchers, and the majority of those surveyed in the studies reporting they had lost weight to compete, a conclusion can be drawn about the prevalence of rapid weight loss in combat sports. Rapid weight loss is a widely practiced method. Some of the weight lost comes via restricting fluids, heated training rooms, and training in rubber suits *(*Artioli, Gulano, et al., 2010; Brito et al., 2012; do Nascimento et al., 2020; Hillier et al., 2019; Connor and Egan, 2019).

Rapid Weight Loss Methodology

The methods used to achieve rapid weight loss are varied and include a multitude of approaches. This section will review some of the methods and practices athletes of various combat sports engage in. Many of the methods listed in the previous section are self-explanatory such as the wearing of rubber or plastic training suits inside a heated training room or sauna. Therefore, this section will focus on the extreme methods undertaken by athletes as well methods that may be unfamiliar or lesser known.

Water loading and hot water baths

Conor and Egan (2019) in their survey of 30 MMA athletes from Dublin found that two of the most reported methods used were water loading and hot saltwater baths. Water loading was also reported to be a common method used in MMA athletes (72.9% reporting either “always” or “sometimes”) by Hillier et al. (2019) in a larger study.

Reale et al. (2017) looked at the effectiveness of water loading on acute weight loss in combat sports athletes. Water loading was defined as the process of temporarily increasing water consumption over the course of several days, followed by subsequent fluid restriction. This process manipulates urine output as well as renal hormones which leads to an increase in fluid loss (Reale et al., 2017). The study took place over an 8-day period and consisted of two groups (control and intervention). There were 2 days prior to the 6-day intervention period as well as on day 6, there being a “post” testing period. The 21 participants included in the final testing period were athletes from different grappling sports (jiu-jitsu, judo, and wrestling) with competitive experience. These individuals were then split into blocks which were matched for body mass, randomized, and placed into either the control or intervention group. Physical performance tests, body composition, and body mass assessments were conducted. The athletes were also given standardized diets and controlled training schedules which attempted to mimic competition preparation. Other tests included urinalysis, blood collection and hormone analysis, heart rate and blood pressure measurements. Reported gastrointestinal symptoms potentially caused by the water loading process were also recorded. The water loading protocol consisted of the first two days prior to the 6-day intervention period being for initial body composition assessments as well as both physical performance test familiarization and pretest performance measurements. These two days consisted of a free unstandardized diet and unrestricted fluid intake. On day 1 of the 6-day testing period, diets became standardized for both the control group as well as the intervention group. Training also became standardized. This consisted of training during the day and night for 3 consecutive days. Day 4 only training at night, and day 5 which had no training. Day 6 was the posttest period. The water intake for both the intervention and control group was as followed. On day 1 of testing, the participants in the intervention group had to consume 100 ml/kg of water for 3 consecutive days. The control group consumed 40 ml/kg of water for 3 consecutive days. On day 4, both groups consumed only 15 ml/kg of water. On day 5, lab data was collected in the morning and the participants were given a rehydration protocol to commence after testing. Results indicated that in the intervention group, 3 days of increased water consumption (100 ml/kg) followed by fluid restriction was effective in manipulating body mass and increasing fluid output. The cumulative body mass change between control and intervention groups on day 5 was 2.5% for the control group as opposed to 3.5% in the intervention group. This study supported water loading as a practice to effectively manipulate body mass in a short period of time.

Hot water baths were another mentioned method used by combat sports athletes. Conor and Egan (2019) in their survey of MMA athletes reported 76% of 30 surveyed MMA athletes in their study reported they either "always" or "sometimes" used hot water baths to cut weight before competition. Conor, Shelley, and Egan (2020) described the process of hot water bath immersion as a passive form of weight loss in which the athlete lies in a hot bath for a period of time. Following the immersion in water, athletes get out of the bath, then wrap themselves up in either blankets, towels, or clothes, to continue sweating and continue the fluid loss. As far as the effectiveness of this method, the aim of the study by Conor, Shelley, and Egan (2020), was to look at both the effectiveness of hot water immersion, but in addition, also sought to look at whether the addition of salt in the baths made any difference in the effectiveness of weight reduction. In the study, 11 male MMA fighters with previous experience cutting weight were the participants. The protocol consisted of 2 separate trials which compared freshwater bathing to saltwater bathing. In both trials, the participants submerged themselves in a bath for 20 minutes, followed by 40 minutes of wrapping themselves up in heavy clothes and or blankets. This was done twice. In both the freshwater bath and saltwater bath trials, the protocol was identical, except for the addition of salt to the water in the saltwater bath trial. The temperature of the water was approximately 37.8°C. The results of the experiment showed a total loss of body weight across experimental protocols to be 3.92 +/- 1.22 kg for freshwater bath, and 3.84 +/- 1.35 kg for saltwater bath, respectively. Weight regains showed an increase of 2.97 +/ - 1.15 kg for freshwater bath, and 3.14 +/ 1.04 kg for salt water, respectively. Both methods were described as similar to one another in terms of results obtained with only minor differences in weight lost and regained following each protocol. Both water loading and hot water baths seem to be effective means of achieving rapid weight loss.

Issues and concerns of safety regarding both hot water baths and water loading have been discussed. More so with water loading due to the potential manipulation of the bodies' renal hormone levels and the risk of hyponatremia. However, according to Reale et al. (2017), when it comes to water loading, it appears to be a safe means of cutting weight provided an adequate recovery period and rehydration protocol are allowed and implemented by the athlete. This time period allows for the adjustment of renal hormones back to baseline levels and spacing out of the ingestion of fluid throughout the day appears to allow the kidneys to adjust to the increase in fluid intake and lower the risk of hyponatremia. Safety concerns with hot water baths were also addressed by Conor, Shelley, and Egan (2020), with athletes being able to put back on a majority of the weight they lost following the weight loss protocol.

Extreme Methods

Extreme methods of rapid weight loss are rare; however, they are sometimes utilized by athletes towards the end of a weight cut to lose the last remaining ounces necessary to make weight. Examples of extreme methods include laxatives, diuretics, vomiting, and diet pills. Artioli, Scagliusi et al. (2010) included these extreme methods in the original development of the RWLQ. Each method's goal is to attempt to decrease an individual athlete's body mass. The use specifically of diuretics and laxatives and how they affect weight loss and potentially performance will be described in this section.

Arumugham and Shahin (2020) described the mechanism in which diuretics work to shift the fluid balance in the body. Certain diuretics work via suppressing the receptors whose primary function is sodium reabsorption. This increases the osmolality of the renal tubules which suppresses water reabsorption leading to an increase in excretion rate. However, multiple classes of diuretics exist, so this mechanism is a generalization. The multiple classes of diuretics are classified by the diuretics' specific mechanism, and their action site along the nephron. Diuretics are used to treat a variety of illnesses from hypertension, pulmonary edema and liver cirrhosis (Arumugham and Shahin, 2020). However, diuretics are sometimes misused by combat sports athletes seeking only to decrease their body weight by increasing water excretion. Diuretics when taken allow for a large quantity of fluids and sodium to be excreted which decreases body mass in the process. The danger lies for the athlete seeking to decrease body mass in taking diuretics without medical supervision. The athlete could take too much and cause a dangerous drop in fluid levels. When diuretics are added on top of other methods such as increased training, saunas, wearing plastics suits, and or hot water baths, the risk to the athlete's health comes in jeopardy and increases the risk of adverse effects. This is also a cause for concern with laxative abuse as well.

According to Roerig et al. (2010), laxative abuse generally has four groups of individuals who abuse laxatives. One group of people who make up a large portion of those affected by laxative abuse are individuals who suffer from eating disorders. The second group of individuals who are affected by laxative abuse are middle to old-aged individuals who overuse laxatives due to constipation. The third group of individuals in which abuse laxatives are those who use the drugs to cause factious diarrhea. The last class of individuals in whom abuse laxatives are individuals who compete in a weight class sports, such as wrestlers and combat sports athletes. One issue associated with laxative abuse is hypokalaemia, or low potassium levels. Potassium is the main electrolyte found in the stool, and hypokalaemia has associated symptoms such as general muscle weakness but can progress into more severe symptoms such as rhabdomyolysis and cardiac arrhythmias. When this is looked at from a sports performance perspective and for the combat sports athlete looking to lose weight, the potentially lowered potassium levels before competition from laxative abuse can mean poor muscle performance. Lacking sufficient potassium does not allow for the proper function of the sodium-potassium pump which plays an important role in neuronal action potential (Pirahanchi et al., 2020). This means poor muscle contraction and poor sports performance.

When athletes use these extreme weight loss methods, there could be the potential risk of crossing over into developing an eating disorder. According to Sundgot-Borgen et al. (2013), the reason for why or how athletes cross the line from dieting and extreme-weight loss methods into clinical diagnosis of an eating disorder (ED) is unclear due to a lack of research on the subject matter. When it comes to weight class specific sports, weight loss is essentially seen as a part of the sport, and with a measured and reported high prevalence across multiple combat sports as discussed in the previous section, if the athlete chooses not to engage in rapid weight loss behaviors, then they are seemingly in a minority of athletes.

Organizational Rules and Policies on Rapid Weight Loss

To limit the magnitude and potential dangers of rapid weight loss, rules have been implemented by federations such as the International Judo Federation (IJF) and NCAA wrestling which either limit the magnitude of an athlete's cut and or the methodologies the athlete is able to use during a cut. The IJF has implemented what are known as random weigh-ins. During these random weigh-ins, athletes cannot weigh in more than 5% higher than the maximum weight for the category that the athlete is registered for. However, only 4 athletes from each weight category are selected via a randomized software program. Not all the athletes will be subject to random weigh-ins (International Judo Federation, 2019). NCAA wrestling has come up with a rule of thumb known as the 1.5% rule. In it, athletes are recommended to not reduce more than 1.5% of their body weight a week via dehydration. In addition, NCAA wrestling has prohibited methodologies such as saunas, laxatives, vomiting, steam rooms, diuretics, and rubber suits as well as heated training rooms (temperatures over 80°F) as a way of mitigating body mass loss via dehydration (NCAA Publications, 2019). NCAA wrestling suggests a caloric deficit and increased exercise to lose the weight, meaning a more gradual and slow process.

Marttinen et al. (2011) made mention of considerations of the NCAA rules regarding weight loss practices while studying the performance effects of self-selected rapid weight loss in collegiate Division I wrestlers. In the study, Marttinen et al. (2011) prohibited/discouraged participants in the study from utilizing prohibited methods as laid forth by the NCAA and made the consequences of engaging in prohibited methods in the study clear.

The Ultimate Fighting Championship (UFC) does not have specified organizational rules against methods used for weight cutting nor does the UFC have rules limiting how much weight the athlete can cut to compete. However, the UFC has employed the United States Anti-Doping Agency (USADA) and the UFC complies with the rules set forth by USADA. USADA's goal per the 2019 UFC athlete handbook is to prevent cheating in the sport via performance enhancing drug use (United States Anti-Doping Agency, 2019). With the adoption of these anti-doping rules set forth by USADA, the UFC has indirectly had an impact on the weight cutting protocols and procedures of the athletes. Under the USADA rule set and as laid forth in the athlete handbook, the unauthorized use of diuretics and masking agents are prohibited (United States Anti-Doping Agency, 2019). These rules also include the use of IV's for rehydration purposes due to intravenous fluids manipulating plasma volume which can mask certain performance enhancing substances (Pomroy et al., 2020). The specific rule for IV use was initially put forth by the World Anti-Doping Agency (WADA) and eventually adopted by USADA. The rule states that, "intravenous infusions and/or injections of more than a total of 100 ml per 12-hour period," are prohibited (World Anti-Doping Agency, 2020, p. 6). The regulation of these two methods of weight loss and rehydration for the initial purpose of preventing doping in the sport has indirectly had an impact on how much weight an athlete can lose and regain via dehydration in the UFC. Examples of extreme cuts are still present within the organization. An athlete named Craig White as recently as 2 years ago in a short notice fight with Neil Magny at UFC Fight Night 130: Liverpool in 2018, claimed to have cut 46 pounds in 2 weeks, dropping from a reported 216 pounds to the 170-pound weight class that White was scheduled to fight in (Carroll, 2018).

The state athletic commissions also play a role in the US because of some state's larger involvement with combat sports and therefore the practice of rapid weight loss. Each individual state has their own athletic commission, apart from a few, (Alaska for example being one that does not have an athletic commission) which sets rules in which competing athletes must comply with if the athlete wants to compete and be licensed to fight and compete in that state. A state in which is becoming more involved in instituting guidelines on weight cutting is California and the California State Athletic Commission (CSAC). At a CSAC meeting that took place on October 15, 2019, Andy Foster, executive officer for the CSAC proposed a motion to the commission members as well as the chair and vice chair of the CSAC to limit the amount of weight an athlete is able to regain (California Department of Consumer Affairs, 2019). The proposed limit was 15%. This means that from the time of the weigh-in to the time of the fight, an athlete cannot regain more than 15% of his or her bodyweight at the time of the weigh-in or the bout would be cancelled (California Department of Consumer Affairs, 2019). For example, if a fighter weighs-in at 185 pounds, if a fighter weighs-in the next day at more than 212.7 pounds, then the fight would not be allowed to take place. The motion was passed via a unanimous decision 5-0 with the law going into effect later this year (2020) in October (California Department of Consumer Affairs, 2019).

As put forth by Franchini, Brito, and Artioli (2012), other solutions to quell rapid weight loss, particularly weight loss of high magnitudes include matches starting within 1 hour of the weigh in and making an athlete have to have a hydration test to have the weigh-in validated. Both direct and indirect organizational rules and regulations have been implemented to dissuade athletes from engaging in extreme weight cutting behaviors and both guidelines and recommendations have been proposed by researchers in literature reviews and studies conducted. Considerations for developing dehydration protocols for future studies examining the effects of rapid weight loss should take into account the rules and regulations of the governing combat sports organization in which presides over the sport in which future studies draws its' participants from to accurately reflect the confines and circumstances an athlete has to compete under.

The effects of rapid weight loss and/or dehydration on physical performance measures in a general context will be reviewed in this section. The effects of rapid weight loss on physical performance will also be examined within the context of combat sports. The terms and performance measure tests will be defined and described. Research done outside the context of combat sports that, examines the relationship between dehydration and physical performance effects will also be discussed.

Dehydration effects on VO_2 max levels/aerobic capacity

Ranković et al. (2010) has defined maximal oxygen uptake (VO_2 max) as the maximum amount of oxygen consumed at a given unit of time during exercise of increasing intensity which cannot be increased. VO_2 max is a measure which evaluates the totality and efficiency of the aerobic processes within an athlete. VO_2 max also examines the aerobic capacity of an individual and measures both functional capacities and health for the cardiovascular and respiratory systems (Ranković et al., 2010). Aerobic capacity depends on aerobic metabolism which was defined by Matsakas and Patel (2012) as:

> "Aerobic metabolism refers to an energy-generating system under the presence of oxygen as opposed to anaerobic, i.e., oxygen independent metabolism. Aerobic metabolism uses oxygen as the final electron acceptor in the electron transport chain and combines with hydrogen to form water [1]. In essence, the vast majority of adenosine triphosphate (ATP) synthesis takes place via aerobic breakdown of energy substrates through the coupling of respiratory chain and oxidative phosphorylation. Aerobic metabolism includes in terms of energy sources carbohydrates and lipids and to a less extent proteins" (p. 29)

Compromised aerobic systems through participation and/or utilization of methods such as rapid weight loss and dehydration in addition to underdeveloped aerobic metabolic processes and aerobic capacity are factors which are detrimental to achieving success in sports from any discipline or level of competition.

Cheuvront and Kenefick (2014) conducted a comprehensive review that suggests that dehydration of greater than or equal to 2% of body mass lost can impair endurance performance in athletes. Cheuvront and Kenefick (2014) also found that dehydration between 2 to 4% can reduce VO_2 max, but may not affect strength and power in athletes. This reduction in body mass between 2 to 4% was also found to have a negative impact on time to exhaustion during endurance activities. However, in a study by Zouhal et al. (2011), they found the opposite. There was an inverse relationship between body mass lost and finish time in marathon runners. In a study that included 643 two-kilometer marathon runners, body weight was measured immediately before the race started and immediately after the competitors had crossed the finish line. Results found that marathon runners that finished the race in under 3 hours mean body weight loss was 3.1%. For marathon runners that finished between 3 and 4 hours, the mean body weight loss was approximately 2.5%. For the runners that took greater than 4 hours to complete the marathon, the mean body weight loss was approximately 1.8%. The study by Zouhal et al. (2011) and the relationship shown between lower marathon finish times and higher levels of dehydration experienced may have a simple explanation. The quicker the marathon run time; the more physical exertion is experienced by the athlete. This increase in physical exertion may increases the sweat loss rate and lead to a higher level of dehydration.

Exacerbating and Masking Factors

Judelson et al. (2007) examined hypohydration's effects on muscular performance. To isolate and look specifically at the effect of hypohydration on performance, they accounted for exacerbating factors, (such as caloric restriction, increased muscle temperature, and fatigue caused by type of protocol used to induce hypohydration) and masking factors, (such as endurance training which helps counteract the physiological effect of hypohydration by causing an increase the body's total water by increasing fluid reservoirs in the body which decreases the effects of hypohydration), menstrual status in women (which hormonally, causes women to increase water retention and potentially mitigate the effects of hypohydration), and the test type used when they examined the research on performance measures. Out of the 70 articles that were reviewed concerning muscular strength and hypohydration, 15 out of the 70 articles analyzed showed a statistically significant decrease in strength. It was suggested that after reviewing the data and when accounting for exacerbating and masking factors in the studies, a 3 to 4% reduction in body weight reduced muscular strength by approximately 2%. In the same review article, power, and the effects hypohydration had on it were examined as well. A total of 47 articles were reviewed and only nine of the articles showed significantly significant decreases in power which suggests that a 3 to 4% reduction in body weight reduces power output by approximately 3% when accounting for exacerbating or masking variables.

Dehydration effects on Anaerobic Performance

Anaerobic performance is defined as the work capacity or sports performance during which maximal intensity exercise has a sustained effort from approximately 10 seconds in length to around 100 seconds (Raeburn and Dascombe, 2009). The substrate used for anaerobic exercise due to a higher intensity of activity is generally carbohydrate dependent once intensity of activity crests over approximately 60% of an athlete's VO_2 max (Baker et al., 2015). The anaerobic metabolic processes occur without oxygen. This energy system utilizes stored glycogen within the muscles as well as from the liver as a source for rapid energy delivery during the higher intensity bouts. Glycogen is then converted to glucose then shuttled to the bloodstream to fuel the production of ATP. This process, known as anaerobic glycolysis, yields 2 ATP per every 1 glucose molecule per turn of the cycle (Melkonian and Schury, 2020). However, during anaerobic processes lasting even shorter in duration, approximately 5 to 6 seconds, the creatine phosphate cycle becomes the preferred option to produce ATP within that period of time (Berg et al., 2002). The creatine phosphate molecule transfers its phosphate group to Adenosine diphosphate (ADP) which rapidly reforms into ATP (Berg et al., 2002). Due to the limited reserve amount of creatine phosphate stored within the body, the supply of ATP which comes from this process can only last for a short duration. Research has been done to examine the effect dehydration has on this energy system's performance.

A study by Jones et al. (2008) examined the effects of active dehydration on anaerobic muscular performance in 7 participants. Participants were required to complete a heat stress trial to induce the dehydrated condition which comprised of 45-90 minutes of treadmill exercise in a hot, humid environment. Following the heat stress trial, the participants were given a 1.5-hour recovery period to attenuate hyperthermia generated from the heat stress trial and reduce the effects of hyperthermia and fatigue. This heat stress trial test was done after a baseline was established in a fully euhydrated state. To test anaerobic power in both the upper and lower extremities, a 30 second Wingate anaerobic performance test was used. Jones et al. (2008) reported that the participants following the heat stress trial experienced an average loss of 3.1% of body mass. When compared with the euhydrated results of the Wingate test, the difference in upper and lower body mean power outputs was -7.17% (upper body) and -19.20% (lower body) and a difference of -14.48% (upper body) and -18.36% (lower body) was observed for peak power output between the euhydrated state and the dehydrated state.

Kraft et al. (2011) also examined the effect of heat exposure and dehydration on anaerobic performance-on 10 male participants which consisted of 3 trials. The first was a control trial in which no dehydration was induced nor were participants exposed to heat. The second trial required the participants to be submerged in a hot water (heat exposure) bath but allowed fluid replacement during the trial. The third and last trial was the dehydration trial in which a 3% decrease in body mass was induced via hot water immersion with no fluid replacement. Each of these trials were separated by 1 week to allow for recovery in between trials. Participants were submerged up to the neck in water that was approximately 39℃ to induce dehydration. Participants completing the heat exposure trial (test 2) consumed water every 15 minutes to keep body mass at the same level. Participants were weighed at different time periods during the hot water immersion (60, 90, and 120 minutes) to keep track of body mass and during the heat exposure trial, and fluid levels were adjusted based on the weights reported by the scale measurements during those intervals to control for body mass in the heat exposure trial. Kraft et al. (2011) determined after a preliminary investigation that dehydration of 3% occurred in approximately 2 hours from hot water immersion. Performance testing for both the heat exposure trial and the dehydration trial only started once core body temperature had returned to within 0.2℃ of initial core body temperature. To test anaerobic performance, 6 sets of 15 second maximal effort cycle sprints were performed on an ergometer with 30 seconds of active recovery in between sets. Mean power and peak power were recorded. Results from showed that mean power was significantly reduced in the dehydration trial when compared to the control trial but not when compared to the heat exposure trial. Peak power was significantly lower in the heat exposure trial when compared to the control trial as well.

Dehydration effects on muscular strength and endurance

Kell et al. (2001) defined muscular strength as the ability of a muscle to produce to produce the maximum amount of force possible over a specific time period and at a specific velocity. Muscular endurance was defined as the ability of a muscle or group of muscles to continually perform work and repeated contractions against a load for a defined, extended period of time. According to the American College of Sport's Medicine (ACSM, 2017), a proper general assessment for muscular strength is the one-repetition maximum (1RM) in which participants lift the most amount of weight possible on a particular lift with the best possible technique for one repetition. This assessment for certain populations could potentially be dangerous or in the case of testing certain populations (such as athletes involved in combat sports) nonapplicable due to the nature of the sport in which is being assessed. The ACSM also acknowledges an estimated one-repetition maximum alternative measurement which bases the participant's one-repetition maximum off of a repetition maximum. Examples of this include a 10-repetition maximum or a 3-repetition maximum. This type of muscular strength assessment is referred to as dynamic due to muscle groups going through both an eccentric and concentric range of motion. Muscular strength can also be assessed using isometric muscle contractions as well where no change occurs in muscle length. The subject contracts the muscle which is being examined as hard as they possibly can and generally for as long as they can sustain. Instead of the amount of weight being lifted being a measure of strength, the time limit in which the subject sustained the contraction for is the standard for which strength is assessed. For muscular endurance, ACSM (2017) recommends the push-up and/or curl-up tests as both good assessments of muscular endurance. This consists of having participants perform a push-up repeatedly until failure or curl-ups until failure. Failure means until form requirements are not met and/or the subject stops performing the movement. While these are not the only two assessments available to researchers when assessing either muscular strength or muscular endurance, these tests are general assessments which are good at assessing general fitness. The effect of dehydration on these performance measures has been conducted and will be discussed.

A study by Greiwe et al. (1998) aimed to examine the effects of dehydration on isometric muscular strength and endurance following a dehydration heat stress trial and a euhydration heat stress trial. 7 participants participated in the study. To test isometric strength, a maximal voluntary contraction against an immovable object to measure peak torque of both the right knee extensors and the right elbow flexors was used. A contraction of five seconds was held and performed three times with two minutes of rest separating each attempt. The highest value of the three was recorded as the peak torque value. After a 5 minute rest period, muscular endurance was tested using the same joints and muscles as was used in the muscular strength test trials. For the muscular endurance tests, participants held a maximal voluntary contraction for as long as possible. Once the measured torque dropped and remained below 50% of the measured peak torque power and remained below 50% for five seconds, the test would end and the time to fatigue was recorded. Both a dehydration heat stress trial and a euhydration heat stress trial were conducted. Both trials consisted of 15-minute intermittent sauna use followed by 5 minutes outside the sauna. The aim of the dehydration heat stress trial was for the subject to lose approximately 4% of their body mass. After this was achieved, the participants were required to relax for 120 minutes to bring down muscle and core body temperature to prevent heat exposure from skewing the results of the muscular strength and endurance tests. Following a 7-day waiting period, the participants came back and performed the euhydration heat stress trial again. The difference being that during the euhydration heat stress trial, participants during the 5 minute break in between sauna exposure, had to drink enough water to maintain baseline body mass levels which was calculated via intermittent use of a scale. Results from the study by Greiwe et al. (1998) showed that no significant difference existed between dehydrated muscular strength and endurance performance and baseline performance.

Périard et al. (2012) conducted a study looking at the effects of moderate dehydration (2.5% body mass loss) on muscle strength and endurance. 10 participants were tested over the course of an 11-day period. The first 3 consecutive days were a familiarization period for the participants being tested on the protocols and methods that were being used for dehydration and what was going to be asked of the participants. On days 4 and 5 and again on days 10 and 11, participants either underwent the dehydration protocol or remained fully hydrated. The dehydration protocol consisted of having the participants walk on a treadmill for ~2.5 h at 5.5 $km \cdot h^{-1}$ up a 5% gradient in ambient conditions of 35°C and 60% relative humidity. The tests used to assess muscular strength and endurance consisted of one 5 second maximal voluntary isometric contraction of the dominant leg, and 15 consecutive 3 second maximal voluntary isometric contractions of the non-dominant leg interspersed by 2 seconds of recovery with electrical stimulation superimposed at 2 seconds on maximal voluntary isometric contractions rep numbers 1, 5, 10 and 15. Electrical stimulation was superimposed at 3 seconds following the 3 second contractions. Lastly, three maximal handgrip flexions of the dominant hand. These tests were done prior to undergoing the dehydration protocol to establish a baseline, immediately following the dehydration protocol and the morning after the dehydration protocol had been done by the participants. During the experimental period, following the administration of the dehydration protocol, participants were asked following the immediate post muscular function test to only consume 500 ml of water and consume only a light meal overnight in order to maintain the levels of dehydration established from the dehydration protocol that afternoon. The participants were given time, food, and a small amount of fluids during a 16 hour latency period between tests. This was to allow for core body temperature to return to normal and for the participants to recover from the fatigue generated by the dehydration protocol. During the euhydration period, the participants remained fully euhydrated and body mass remained consistent across the three muscular function testing intervals. Participants were asked to consume a typical overnight meal in between muscle function tests two and three. Results from the study indicated that brief maximal force production was unaffected by dehydration. During the repeated maximal voluntary isometric contraction trials, a significant decrease in force production was observed, regardless of hydration status. However, it was noted that those decreases in force production during the repeated maximal voluntary isometric contraction trials could be because of the acute dehydration experienced by the participants enhancing the fatigability of the muscle mainly caused by the exercise-induced heat stress.

Savoie et al. (2015) examined levels of hypohydration and associated performance effects on muscle endurance, strength, and anaerobic power and capacity. Analysis of 28 studies indicated that levels of hypohydration had an overall negative effect of 8.3 ± 2.3 % on muscular endurance (no significant difference between upper and lower body endurance); a 5.5 ± 1.0 % negative overall effect on muscular strength (no significant difference between upper and lower body strength), and a 5.8 ± 2.3 % negative overall effect on anaerobic power when hypohydration is present. However, both anaerobic capacity and vertical jumping ability were not significantly altered with levels of hypohydration.

Dose-dependent Response of Dehydration

One final study done by Hayes and Morse (2010) looked to examine the relationship between dehydration and the potential dose response it has on strength and power. 12 male participants participated in a dehydration protocol which consisted of 5 periods of 20 minutes of jogging at certain points up to 80% of age predicted heart rate in an environmentally controlled chamber. The highest mean temperature available to be reached in the chamber was approximately 48.5°C. After each period of running, participants completed 3 standing vertical jumps (SVJ) conducted using a force platform as a measure of lower body power with a minute rest in between each of the 3 reps. The largest measured total displacement was used. Both isometric and isokinetic tests were conducted following the standing vertical jump test. Both isometric and isokinetic measurements were conducted on an isokinetic dynamometer machine by way of a unilateral right knee extension. At a knee angle of 60°, participants were instructed to develop as much force as they possibly could within the shortest amount of time and instructed to hold that contraction for 5 seconds to test isometric strength. This was done a total of 3 times with 1 minute of rest in between each trial. The highest peak torque was recorded and measured by way of electromyography of the vastus lateralis. Isokinetic strength was measured via the isokinetic dynamometer, using two different angular velocity speeds ($30°s^{-1}$ and $120°s^{-1}$), each one done 3 times with a minute rest in between each repetition. Again, the highest peak torque was recorded via electromyography. These tests were conducted after each 20-minute jog period for a total of 6 times, which included the trial done before exposure to the environmentally controlled chamber. The test stopped once one of five criteria were met. The athlete lost 5% of their body mass, core temperature exceeded 39.5°C, displaying signs or symptoms of an exercise-induced heat illness, a request to stop exercising or, five exposures were completed. The results of the study indicated that no significant changes were observed across trials in standing vertical jump height. Isometric leg extension strength was significantly affected following the first exposure trial and subsequent trials thereafter. Isokinetic strength at the angular velocity of $30°s^{-1}$ was significantly affected after trials 3, 4, and 5 when compared to baseline results. Isokinetic strength at a rate of $120°s^{-1}$ was unaffected.

While the goal of this literature review is to outline and examine the physical performance effects in combat sports athletes following a period of rapid weight loss, it is important to look at the general physical performance effects of dehydration studied in populations outside of the combat sports community. Many methodologies for rapid weight loss utilized by combat sports athletes involve dehydration. Be it through training in plastic or rubber suits, heated training rooms, water loading, hot water baths, saunas, restriction of fluids, or even more extreme methods such as diuretics or laxatives (Conor and Egan, 2019, do Nascimento et al., 2020, Artioli, Gulano et al., 2010). Some of the research that is presented in this section, utilizes some of the same methods combat sports athletes use to achieve rapid weight loss as well such as hot water baths (Kraft et al., 2011), saunas (Greiwe et al., 1998), and the use of heated training rooms combined with physical activity (Périard et al., 2012, Hayes and Morse, 2010). The difference between the populations discussed in this section and the combat sports athlete population is that studies concerning the effects of rapid weight loss on physical performance measures within the combat sports community will include athletes with previous experience in RWL given the prevalence of the practice in combat sports (Artioli, Gulano, et al., 2010, Brito et al., 2012, do Nascimento et al., 2020, Conor and Egan, 2019, Hillier et al., 2019, da Silva Santos et al., 2016, Dugonjić et al., 2019). This previous experience with rapid weight loss could potentially dampen the magnitude of performance effects experienced by combat sports athletes due to a familiarity that the athletes have with the process and could be an area of future study.

Physical and Physiological Profiles of Combat Sport Athletes

The term "combat sports" encompasses a wide variety of disciplines, each of which requires its own set of physical performance standards to be competitive in that discipline across levels of competition. Strength and power measurements, muscular endurance, aerobic capacity, and anaerobic capacity have been collected and analyzed in systematic literature reviews by researchers across multiple combat sports. This is done in large part to gain an understanding of the physical demands of each sport. For the purposes of this research, this section will present these profiles to quantify later, how much of an effect rapid weight loss and dehydration has on the physical performance of combat sports athletes by presenting averages and ranges which have been studied and presented by researchers through systematically reviewing the literature available. Below, studies will be presented and discussed which have analyzed the physiological profiles of wrestlers, amateur boxing, Brazilian jiu-jitsu, and taekwondo athletes. At the end of the section, similarities and differences between physiological profiles will be discussed as well.

Physiological Profiles of Wrestlers

Chaabene et al. (2017) performed a systematic review of the literature to analyze the physiological profiles of wrestlers. A total of 71 studies were analyzed based on inclusion and exclusion criteria which aimed to look at the physical and physiological performance measures of wrestlers from a wide variety of competitive levels. On average, wrestlers had a wide range of reported VO_2 max levels for both males and females. These numbers were similar to other reported VO_2 max levels in other combat sports. Wrestlers had similar anaerobic measurements to combat sports such as Judo and karate, and similar maximal dynamic strength numbers when compared to other grappling sports such as Judo. Wrestlers had higher maximal dynamic strength than striking sports athletes such as Taekwondo and Karate.

The broad range in the VO_2 max numbers in both men and women wrestlers comes from according to Chaabene et al. (2017), the wrestler's level of practice and experience, what training phase the athlete is currently in, the mode of testing done to gather the data, and the differences in weight categories. When compared to other combat sports athletes, ranges of VO_2 max found in wrestlers were comparable and like those athletes found in karate, taekwondo, judo, and amateur boxing for both men and women.

In terms of anaerobic capacity, values in both Mean Power (MP) output and Peak Power (PP) output among wrestlers are like those found in judo, amateur boxing, and karate (Chaabene et al. 2017). While male wrestlers presented a similar anaerobic capacity to some combat sports, male wrestlers also had higher anaerobic capacities when compared to other combat sports athletes as well. Due to a change in international competition rules to three rounds lasting two minutes with a 30 second break in-between, there would be a greater reliance on anaerobic metabolism given the time constraints imposed on the athletes by the rule changes (Chaabene et al., 2017).

Yoon (2002) had stated that along with the changes to the rules in recent years, that the time constraints in competition could also determine the type of athlete who will be successful in competition as well as dictate the type of training that wrestlers will need to implement more of in the future in order to increase their chances of success.

One final note, the wide range of data sets for maximal dynamic strength was explained as being because of two reasons. One reason is different competitive level of wrestlers being included. The second reason is the differences in weight categories (Chaabene et al., 2017). When the ranges for maximal dynamic strength are compared to other combat sports, the numbers for wrestlers were higher than those reported in Taekwondo and karate athletes but were like those in Judo. The same was found to be the case concerning muscular power; wrestlers were comparable in power output (via vertical and horizontal jump test measures) to

Judo athletes and higher than those athletes in karate and taekwondo. These similarities found between strength and power in Judo and wrestling could be explained by reasoning that because both wrestling and Judo are grappling sports, there would be some similar demands in some aspects of each sport. McGuigan, Winchester, and Erickson (2006) discovered that in the testing of maximal isometric strength values (via mid-thigh pull exercise) in collegiate Division III wrestlers, when compared to previous research of Division I collegiate wrestlers, the levels of measured maximal isometric strength values were greater in the Division I athletes than in the Division III athletes. This research may support the point that success in wrestling is dependent upon generation of greater maximal isometric strength values. Appendix C provides a summary of the results and ranges from Chaabene et al. (2017).

Physiological profiles of Brazilian Jiu-Jitsu Athletes

Andreato et al. (2017) performed a systematic literature review to examine the research available on the physiological and physical profiles of Brazilian Jiu-Jitsu athletes. 58 studies were included in the review which looked at the major fitness components associated with Jiu-Jitsu. Appendix D will include the results from the study concerning the aerobic and anaerobic data ranges of the athletes as well as the muscular strength, muscular power, and muscular endurance data ranges collected in the study.

VO_2 max ranges were similar when compared to other combat sports such as judo, but given the fluctuations in effort and intensity during jiu-jitsu matches because of varying factors such as the pace being set by both the competitor and the competitor’s opponent, VO_2 max and it’s direct contribution to success and role in jiu-jitsu is difficult to quantify as opposed to sports such as Taekwondo and Karate. For both Taekwondo and karate, the role of increasing aerobic capacity and maximizing VO_2 levels is associated with increased levels of sporting success. Handgrip strength is a crucial point of sporting success in jiu-jitsu given that it is a grappling sport which is defined by establishing grips and maintaining them, especially when wearing the Gi. When compared to the results found by Chaabene et al. (2017) in the review conducted in wrestlers, handgrip strength of jiu-jitsu athletes seems to fall in line with what was reported for elite male senior level competitive wrestlers.

No anaerobic data or ranges were included in the table below. Andreato et al. (2017) was only able to cite two studies in the review concerning anaerobic data of Brazilian Jiu-Jitsu athletes for lower limb power output using the Wingate test. One study which was conducted by Del Vecchio et al. (2007) and the other study by Leitão da Silva (2015). Both studies conducted the Wingate test on lower limbs using 7.5% of the relative body mass of the athletes. Del Vecchio et al. (2007) reported values of peak power (10.1 ± 1.2 W/kg), mean power (9.9 ± 1.4 W/kg) and a fatigue index (48.2 ± 9.4%), respectively. Leitão da Silva (2015) reported findings of peak power (11.5 ± 1.4 W/kg), mean power (9.8 ± 0.4 W/kg) and a fatigue index (56.5 ± 11.0%).

As far as a lack of data on the physiological and physical profiles of female competitors in Brazilian Jiu-Jitsu, Andreato et al. (2017) only reported two studies of female athletes, both of which were concerning body composition. No measures of strength, power, aerobic capacity, anaerobic capacity, or muscular endurance were present or had been studied in women in jiu-jitsu.

Physiological profiles of Taekwondo Athletes

Bridge et al. (2014) conducted a systematic review to analyze the physical and physiological characteristics of Taekwondo athletes. Appendix E will include data from the review on the anaerobic capacity, aerobic capacity, muscular power and muscular endurance ranges of Taekwondo athletes.

The disparity in VO_2 max ranges reported by Bridge et al. (2014) was due to 2 reasons. One, that of individual differences in structure of training and phase of training the athletes were in during the time of testing. Secondly, the modes of exercise testing performed by the researchers who collected the data (treadmill vs cycle ergometer) were also a contributing factor in the ranges of data. When VO_2 ranges were collected and compared to other combat sports athletes, the ranges for the Taekwondo athletes were similar and fell within the standard range observed in most combat sports athletes (Bridge et al., 2014). Whether or not an adequate level of aerobic fitness leads to success at different levels of competition in Taekwondo remains to be seen. According to Bridge et al. (2014), this is due to the limited diversity of research available which looks at medalist's vs non-medalists' VO_2 max levels. When power outputs were collected via static jump, squat jump, and countermovement jump tests and compared with data collected from other international and national level combat sports athletes (Judo, Karate, and Pencak Silat), taekwondo ranked poorly when it came to lower limb muscular power. According to Bridge et al. (2014), given the small sample sizes and limited number of studies, interpretations and conclusions on the data should be withheld until further research is conducted.

Physiological profile of amateur boxers

A review by Chaabene et al. (2015) examined the physiological profiles of amateur boxers. Results and data from the study are presented in a table on Appendix F.

Data was presented for muscular strength, power, and isometric strength measurements. Data ranges for punch force however were broad which potentially makes statistical analysis difficult due to outliers and other factors. As hypothesized by Chaabene et al. (2015), the broad ranges in data may be due to different measurement devices among studies which were included. In addition to this, differences in punching power were also attributed to technique differences as well as anatomical and physiological differences between subjects in studies. For instance, a punch which travels a longer distance due to differences in the actual punch being performed (i.e. a hook vs. a straight punch) and/or differences in subject limb length along with punches which are thrown from either the rear hand or lead hand. Both factors lead to a greater overall distance travelled and a potential difference in power. Differences in maximal punching power were noted between elite and intermediate level competitors, and intermediate and novice level competitors. Elite level competitors had a higher mean maximal punch force when compared to intermediate level competitors. Intermediate level competitors had a higher mean maximal punch force when compared to novice level competitors. This seems to support the notion of punching power being an important distinguisher between skill levels.

Tests concerning power among amateur boxers was reported to be limited in both upper and lower body measurements. As listed in Appendix F, the shot-put test was reported as a reliable measurement of upper body power development in boxers due to the power generation developed by boxers when throwing a straight punch being similar to that of throwing the shot-put.

Finally, isometric strength measurements were reported only in 3 studies. Potential positive correlations between hand grip strength and the ability to generate power in punches as well as correlations between competition ranking and high levels of isometric handgrip strength were discussed but definitive results were not able to be deduced.

Comparing the four studies and reviews leads to some conclusions about testing physical and physiological profiles of combat sports athletes. Tests of aerobic profiles, anaerobic profiles, power, strength, and muscular endurance showed that multiple modes of testing were used to assess the different characteristics of each athlete. The wide range of VO_2 max levels for instance were explained by both Chaabene et al. (2017) and Bridge et al. (2014) as being due to the varied modes of testing being used to assess the aerobic profiles of the athletes. Standardized testing for testing physiological profiles of combat sports athletes would make finding a more accurate range of data easier and comparison of data ranges across combat sports easier as well. However, not all labs or settings are created equal. Some labs may not have access to the equipment necessary.

In terms of testing the anaerobic characteristics, muscular power, and muscular endurance of combat sports athletes, the Wingate test, the countermovement jump or broad jump test, and the push-up and sit-up test seemed to be the preferred methods of testing anaerobic profiles, muscular power, and muscular endurance in athletes respectively (Bridge et al., 2014, Andreato et al., 2017, Chaabene et al., 2017). Comparisons of grip strength and endurance among combat sports, particularly grappling sports such as jiu-jitsu, wrestling, and judo is a beneficial comparison to make because of the emphasis and importance of establishing grip position and your ability to maintain those grips during the competition. As reported by Chaabene et al. (2017), handgrip strength in wrestling is critical to success due to its importance in establishing and maintaining certain holds and allows for the competitor to grasp and control the opponent's movement. The same could be said for Brazilian Jiu-Jitsu and Judo. The establishment of grips on the collar, sleeve, or pants in Gi jiu-jitsu and maintaining those grips allows the competitor to control the opponent's movement and be in a better position to execute a technique.

For both jiu-jitsu and taekwondo, more data needs to be acquired for anaerobic characteristics given that a limited amount of data and research was reported by both Andreato et al. (2017) and Bridge et al. (2014). While the Wingate test is absolutely an adequate test of anaerobic power and capacity, a point made in the literature by Bridge et al. (2014) suggested that the test lacks mechanical specificity in terms of mimicking the anaerobic actions of taekwondo which may undermine the validity and accuracy of the test results to some degree. This point made by Bridge et al. (2014) was also pointed out in the literature by Chaabene et al. (2017) for testing anaerobic power and capacity in wrestlers and by Andreato et al. (2017) for assessing anaerobic power and capacity in jiu-jitsu athletes as well. As seen with the study by Chaabene et al. (2014) concerning amateur boxers, the assessment which was used to judge maximal strength was punching power, not a one repetition maximal test. The one repetition maximal test was used to assess strength in taekwondo athletes by Bridge et al. (2014), which is a striking sport as well. Perhaps for future studies examining maximal strength in striking sports, both one repetition maximal tests as well as sport specific tests should be utilized to standardize results. While a one rep max test will give you an idea of general strength using typically a compound movement such as a bench press or squat, the striking power assessment using a force plate embedded in a pad is more sport specific.

Effects of Rapid Weight Loss on Physical Performance in Combat Sports

The literature on the physical performance effects of combat sports athletes following a period of rapid weight loss within the past 20 years is somewhat limited. Search efforts were conducted using databases such as PubMed, SportDiscus, Web of Science, and ProQuest. Search terms such as “kickboxing”, “judo”, “mixed martial arts”, “karate”, “Brazilian jiu-jitsu”, “Muay Thai”, “boxing”, “combat sports” and “wrestling” were entered into said databases. Other search terms such as “dehydration”, “hypohydration”, and “rapid weight loss” along with the search terms, “performance”, “strength”, “endurance”, “aerobic”, “anaerobic”, and “power” were also used in various combinations. Exclusionary criteria consisted of only including research done within a 20-year time frame (Jan. 2000-Jan.2020). The reason for this decision was to only look at current research with current being defined as a 20-year period. Inclusionary criteria, while not specified included all age ranges, gender, skill level and experience within a sport. Results of the literature review returned 20 studies which were included in the section after duplicates and studies which did not meet the criteria were excluded.

Effects in performance measures in MMA athletes

The sport of MMA combines multiple disciplines of combat sports including wrestling, judo, karate, boxing, Muay Thai, kickboxing, Taekwondo, and Brazilian jiu-jitsu (Alm & Yu, 2013). MMA has further been described by James et al. (2016) as a sport that is characterized by bouts of explosive and high velocity movements involving various metabolic systems engaged throughout the duration of the matches which potentially could range from 3, 5-minute rounds to, in championship matches, 5, 5-minute rounds. With the potential of competing in a match that could last up to 25 minutes, any decrease in any performance aspect due to rapid weight loss could be detrimental to the outcome of the fight, especially when going into later rounds. With the prevalence and magnitude of rapid weight loss being examined and established in recent studies by Conor and Egan (2019) and Hillier et al. (2019) in MMA, a look at the recent literature over the past 20 years returned few studies concerning the performance effects of rapid weight loss in MMA, however, the studies that were found are presented below.

Alves et al. (2018) studied the physiological function of mixed martial artists following a period of rapid weight loss. 12 participants who were amateur MMA competitors that had 4 years of experience in MMA participated in the study. The isometric handgrip strength test was used as the measure of performance for the athletes in the study. Handgrip strength was tested using a dynamometer with 3 maximal effort attempts with the best of the 3 efforts being recorded. Athletes were also weighed to assess rapid weight loss' effect on body mass. Hydration status was assessed as well. Baseline tests were conducted 10 days before official weigh-in and before water deprivation began. Performance tests following baseline tests occurred at the official weigh-in, and the day of the competition. No limit was set on the athlete's for how much weight they had to lose because the competition that the athletes were taking part in at the end of the study was a true competition and not a simulated competition. Results of the urine density tests found that none of the athletes were classified as well hydrated. 9 of the participants were minimally dehydrated, and 3 of the participants had undergone significant dehydration at the time of the weigh-in. When looking at the results of the urine density tests at match time following the 24-hour period of recovery, only 2 participants were well hydrated, 5 participants were minimally dehydrated, and 5 participants were significantly dehydrated. Mean baseline handgrip strength was measured at 51.7 ± 5.6c kgf, which dropped to 47.8 ± 6.0c kgf on official weigh-in day, and slightly improved to 49.3 ± 5.4c kgf following a 24-hour recovery period. Mean isometric hand grip strength did not return to baseline.

A study by Barley, Iredale et al. (2018) measured repeat effort performance by way of a repeat sled push test. A medicine ball chest throw, handgrip strength test and a vertical jump test were also used to assess upper body power, isometric strength, and lower body power. The dehydration protocol set out to induce a 5% decrease in body weight. Performance testing was done both 3 and 24 hours after the dehydration protocol was administered. A total of 14 participants were assessed, all with at least 2 prior years of amateur competitive experience in MMA. The dehydration and control protocol both involved 3 hours of cycling done at 60 W in a temperature and humidity controlled environmental chamber with the athletes wearing a plastic sweat suit. The only differences between groups during the dehydration protocol were the participants in the dehydration protocol cycled in a 40℃ environment, as opposed to the control group who cycled in a 25℃ environment. The participants undergoing the dehydration protocol were not allowed to consume fluids during the protocol as opposed to the control group who could consume fluids throughout the protocol. Following the protocol, both sets of participants could consume as much fluid and food as they wanted and were encouraged to consume the same amount of food and water as they would in preparation for a competition. To assess repeat effort performance, a sled push was used and loaded with approximately 75% of the subject's body mass and was pushed over a 10-meter distance for a total of 30 times. After each effort, participants were given 20 seconds to recover and then perform the next effort. Peak effort time (fastest 10-meter effort) and mean sled push time (average of all completed 10-meter efforts) were kept track of as well as heart rate and RPE. Upper body power was assessed with a medicine ball chest throw. Lower body power was assessed using a vertical jump test. Grip strength was assessed using a hand dynamometer. All tests, excluding the sled push test, were given 3 maximal efforts with 1 minute of rest in between each effort. When compared to the control group, repeat sled push performance mean time was slower in the group who underwent the dehydration protocol at both the 3-hour performance test period and the 24-hour performance test period. The peak sled push time was also slower in the dehydration group 24 hours later compared to the control group. Hand grip strength, when compared to the control group, in the dehydration group, was impaired 3 hours after the dehydration protocol but not 24 hours after the dehydration protocol. The medicine ball chest throw ability declined in the dehydration group 24 hours later following the dehydration protocol when compared to the control group but not 3 hours later following the protocol.

Camarço et al. (2016) conducted a case study which studied 2 professional male MMA fighters within the same weight category who underwent a period of rapid weight loss. They tested for both isometric strength and muscular power (along with cognitive responses and salivary samples) at 3 different periods of time. Tests were done 7 days before competition, 36 hours before competition day, and on "competition" day. This competition period was simulated to mimic an actual competition period and athletes had 1 week to employ RWL strategies to get down to competition weight and then given 1 full recovery day after weigh ins. Both athletes underwent different magnitudes of RWL. Athlete 1 lost 7.2 kg (approximately 9.1% of total bodyweight). Athlete 2 lost 4.0 kg (approximately 5.3% of total bodyweight). Isometric strength was measured via isometric grip strength using a hand-held dynamometer with three consecutive maximum attempts with a 5 second duration and a 1 minute 30 second rest in between sets followed by switching hands and the best attempt was recorded. Upper body power production was tested using a Smith Machine bench press at 30% of subject's 1RM and measured using a linear position transducer. For lower limb power production, a vertical jump test was used to measure lower limb power production. 5 vertical jumps were performed with a 5 second rest in between every 2 jumps. There were differences in preparation between both athletes. Athlete 2 was under the supervision of a nutritionist, was on a balanced diet, consumed 2 L of water during the first 6 days of the RWL period and only underwent one day of fasting and water restriction. Athlete 1 however, was not supervised by a nutritionist, had an unbalanced diet, consumed 6 L of water during the first 5 days of the RWL period, and underwent 2 days of fasting and fluid restriction. No differences were observed in either athlete in terms of isometric hand grip strength following testing. Muscular power however, decreased in both athletes at weigh in day testing when compared to baseline values. Higher upper limb power values were recorded on competition day for athlete 2 than for athlete 1. It was pointed out by Camarço et al. (2016) that power output was reestablished in athlete 2 who lost 5.3% of total bodyweight but it was not reestablished in athlete 1 who lost 9.1% of total bodyweight.

Barley, Iredale et al. (2018) utilized a physical performance test in which a repeat effort performance was assessed utilizing a sled push to approximate the physical demands of MMA. This test deemed an adequate estimation of the physical demands of MMA due to the test closely mimicking the demands of the sport. Examining the physical performance effects of rapid weight loss within the context of a simulated match for MMA is difficult to achieve or replicate because of the damage the athletes can potentially take due to strikes being involved during the testing. While studies concerning the physical performance effects of rapid weight loss involving grappling sports such as Judo and wrestling have been done using simulated matches (Artioli, Igelesias et al. 2010, Isacco et al., 2019, Koral and Dosseville, Kraemer et al., 2001, Marttinen et al., 2011), using simulated competition to assess physical performance effects caused by rapid weight loss in sports which involve striking proves to be difficult.

A potential area of research in terms of performance effects of rapid weight loss in MMA is the time frame given after rapid weight loss. State athletic commissions such as California in 2016 proposed and passed emergency legislation within their state to give fighters the option to weigh-in up to 30 hours prior to the fight instead of the 24-hour time frame which was allotted to the fighters before. (California State Athletic Commission, 2016). According to Barley, Iredale et al. (2018) as well as Alves et al. (2018), performance effects were still measured up to 24 hours later following a period of rapid weight loss. With the additional 6 hours to recover, this may potentially mean less of a measured performance effect due to more time being given to the fighters to rehydrate. Alves et al. (2018) found that improvement in isometric strength was present between time of weigh-in performance test and day of competition performance test over a 24-hour period, but performance measures did not return to baseline levels in that study. Documentation also of the fighter's rehydration protocol during the 24 to 30-hour recovery period could lead to a greater understanding in potentially optimizing rehydration and decreasing measured performance effects.

Effects in performance measures in Judo athletes

Rapid weight loss is prevalent in Judo (Artioli, Gulano et al., 2010, Brito et al., 2012, Nascimento et al., 2020). Studies which have examined the possible the performance effects of rapid weight loss in Judo are presented below.

A study by Artioli, Iglesias, et al. (2010) examined the effects of rapid weight loss and a subsequent 4-hour recovery period on Judo related performance measures. A total of 14 participants were split into 2 groups. A control group, which consisted of 7 males who were inexperienced with rapid weight loss methods and an experimental group which consisted of 7 males who had experience with rapid weight loss in the past. Both sets of athletes completed testing before intervention. Post intervention testing was between 5- and 7-days following intervention. Between test days, athletes from the control group were asked to maintain their usual food and water consumption patterns and maintain their body weight throughout the entirety of the study. The experimental group were asked to lose 5% of their body weight using whichever methods they preferred (however this excluded the use of diuretics, diet pills, and laxatives) over the course of 5 days. For the final 3 days, athletes from the experimental and control groups were asked to keep a food log to track caloric and macronutrient intake. Performance assessments were as followed. After a 5-minute warm-up, athletes were required to perform 3 bouts of a judo related maximal intensity exercise. Each bout lasted approximately between 10 to 30 seconds with a 10 second recovery in between bouts. Upon completion of the maximal intensity exercise, athletes then rested for 5 minutes. Following the rest, the athletes then competed in a 5-minute judo match. After the match, athletes rested for 15 minutes before performing 3 bouts of a 30 second Wingate test for the upper limbs. Between each bout was a period of 3 minutes of rest. Following the weigh in for the second test, athletes who cut 5% of their body weight were given the opportunity of a 4-hour recovery period before testing occurred as were the control athletes. Athletes could freely consume as much fluid and food as they wanted. On Appendix G, a diagram from the study is included which lays out the testing protocol as well as experimental design. Results of the study concluded that following a period of rapid weight loss, when given a period of 4 hours to recover, the participants' performance was not significantly affected following a period of rapid weight loss.

Isacco et al. (2019) studied the effects that rapid weight loss had on physical, psychological, and biological responses in judo athletes. 20 athletes participated in the study, all of whom had an average experience level of 15 years. Participants were well trained and national level black belt competitors. Following a period of a month of weight maintenance, the 20 participants were split into even groups of 10. One group would keep their weight stable while the other group were asked to lose greater than or equal to 3% of their body mass using a restrictive diet which was typical of the competitors leading up to the competition. At the start of the experimental period, the athletes in the weight loss group had 1 week to lose the required 3% or more. Following the diet, athletes were set to compete in a total of 5 simulated matches, with assessments of physical, psychological, and biological parameters being taken in between each match. 30 minutes of rest was allotted to the athletes in between each match. Physical assessments as well as psychological and biological assessments were performed the morning before simulated competition commenced as well. Physical performance measures used to assess strength and power were a maximal isometric handgrip strength test as well as an anaerobic capacity test of the upper limbs. Maximal isometric strength was measured using a handgrip dynamometer using both the left and right hands. Participants performed a maximal contraction for 3 seconds, with 2 allowed attempts and 30 seconds rest in between measurements. The average of the 2 tests were recorded and used and the test was performed in between each match. To test anaerobic capacity of the upper limbs, a dynamometer was also used. To test upper body anaerobic capacity, a 30 second isometric rowing exercise was performed on a seated chest press machine. This test, along with the isometric handgrip strength test were performed in between every match and before the start of the first match. Results of the study showed an overall decrease in handgrip strength and performance in both groups over time with a significant group to time interaction being observed in maximal isometric strength and overall time at maximal isometric strength at both matches 4 and 5.

Koral and Dosseville (2009) studied the effects of gradual and rapid weight loss on physical performance measures in elite judo athletes. A group of 20 athletes (10 males, 10 females) who had all qualified for the French Junior National Championships participated in the study. Two testing days were conducted for the duration of the study. The first was 4 weeks before the national championship in which competitors were getting ready to compete in. The second test day was one day before the national championship. 10 athletes (5 male and 5 female) were put into the control group and were asked to maintain their current body weight or to not lose more than 2% of their body weight. The experimental group (5 males and 5 females) were asked to lose between 2 and 6% of their body weight with the help of a dietician and their coach. Starting at 4 weeks out, the experimental group slowly decreased their energy intake by 4 MJ over the course of 21 days. During the last 6 days, the experimental group lost weight by implementing rapid weight loss methodologies which consisted of exercising in plastic suits to increase sweat rate and water loss. Performance tests were a vertical jump test, repetitions of judo movements of the athlete's choice and a rowing movement. The vertical jump tests consisted of 6 total jumps (3 standing jumps with no countermovement and 3 countermovement jumps) with a 5-minute rest in between each jump. The best jump height out of the standing jump measurement and countermovement jump measurements were the two measurements that were analyzed. Participants were then asked to perform their favorite judo movement continuously for 5 seconds for 3 trials with a 5-minute rest period in between trials. In addition, one 30 second trial in which the athletes performed their favorite judo movement continuously followed by a 5-minute rest was also performed. The last test asked the athletes to perform 10 rowing movements with 70% of the athlete's maximal developed load. The athletes were asked to perform this task as quickly as possible and the duration of the set was used to calculate mean power. Results between the first and second test in the experimental group showed a significant decrease in performance on the 30 second repetitive judo movement test between both groups with the larger decrement in performance going to the experimental group. No significant difference was measured in the standing jump or countermovement jump performance tests nor in the mean power development test in both experimental and control group.

A study by Morales et al. (2018) examined the effects of rapid weight loss on balance and reaction time in judo athletes along with strength measures via isometric handgrip strength test and an isometric trunk traction strength test. 38 participants (12 females, 26 males) participated in the study with a mean average experience level of 10 years, 5 of which were competing. 2 testing days were conducted. The first test day was one week before the official weigh-in, and the second was conducted immediately after weigh-in. Participants were split into 3 groups. One group which was the control group were asked to maintain their body weight. The two experimental groups consisted of a progressive weight loss group (PWL). This group was asked to lose less than 3% of their body weight via progressive weight loss (PWL). The participants in the other group were asked to lose greater than 3% of their body weight via rapid weight loss (RWL). The rapid weight loss group lost weight via rapid weight loss methods such as dehydration and caloric restriction in a shorter period of time. To measure strength, the standard isometric handgrip strength test was conducted using a hand dynamometer. To measure isometric trunk traction strength, a leg and back dynamometer was used. The athlete grasped a handle while maintaining 30° of lumbar flexion, proceeded to extend their legs and pull on the handle. Each test (maximal isometric handgrip strength and isometric trunk traction strength) had

2 attempts, each of which lasted 3 seconds, the best attempt of each test being recorded. Between tests 1 and 2, there was no observed statistically significant difference in isometric strength between the three groups. Balance as well as reaction time were also measured in this study with findings showing significant decreases in the RWL group for both balance and reaction time tests.

Examining the research in this section, a noticeable similarity between the studies is the magnitude of weight loss requested of the participants to lose. None of the studies required participants to lose more than 6% of their body weight. This is in line with IJF rules who screen athletes via random weigh-ins (International Judo Federation, 2020). These rules and weigh-ins require athletes to be within 5% of the maximum upper limit of their registered weight category (International Judo Federation, 2020). This measure is a preventative one which keeps athletes from engaging in extreme weight cutting behaviors. Future research on the performance effects of rapid weight loss amongst Judo athletes should be cognizant of the rulesets in which Judo athletes compete under to keep the research within context of the sport.

Franchini et al. (2011) made mention that due to the nature of Judo being that of near continual gripping at submaximal intensities rather than that of maximal gripping at maximal intensities, isometric strength endurance is better suited for assessing strength in the context of Judo. This should also be potentially tested and utilized as well in future studies when looking at the physical performance effects of rapid weight loss in Judo athletes rather than a standard isometric maximal grip strength exercise.

Effects in performance measures in wrestlers

Rapid weight loss prevalence and weight manipulation has been occurring and being documented in wrestling as far back as 1970 by Tipton and Tcheng. The prevalence and practice have well and truly been established and understood as part of the sport. The sport of wrestling has been characterized and described by Chaabene et al. (2017) as a sport in which success at a high level in the sport is dictated by the development of certain physical performance attributes. Levels of maximal dynamic strength, isometric strength, explosive strength, and strength endurance are all important characteristics to develop for wrestlers. In addition to those measures. Wrestlers should also develop a high level of aerobic fitness for sustaining effort for the duration of the match. The need for anaerobic fitness (both power and capacity) should be at a high level as well because of the intermittent explosive actions which occur throughout a typical wrestling match. This section will examine some of the research over the past 20 years concerning physical performance effects following a period of rapid weight loss in wrestlers.

Jlid et al. (2013) studied the effects of rapid weight loss on muscular performance in wrestlers. 10 participants who competed for the Tunisian national wrestling team participated in the study. The study was comprised of 2 testing days. One testing day was before the diet commenced and rapid weight loss began. The last testing day was done on the day of the competition. Both tests were separated by 7 days. Testing comprised of an isometric handgrip strength test, an isometric back strength test, and a dynamic postural stability (DPC) test. The isometric handgrip strength test was done using a standard hand grip dynamometer, in which the athletes were given 3 attempts using their dominant hand. 30 seconds of rest was interspersed in between trials and the best attempt was recorded. The test of isometric back strength was performed on a back and leg dynamometer. The athletes gripped a handle while maintaining a back angle of 30° of flexion with knees straight and proceeded to pull upwards with as much force as possible. 3 trials were completed with the best of the 3 being recorded. The dynamic postural control test was measured using the Star Excursion Balance Test. An 8-pointed star is marked off on the ground with the subject standing in the center of the star. The participant proceeds to stand and balance on one leg and proceeds to reach the opposite leg out to the different points of the star when instructed to do so. The 8 lines which made up the star were labeled the direction in which the subject had to reach in relation to the leg in which the subject was balancing on. The test was done using both the right and left leg as the balancing leg. Little information was provided in the study as to how much weight specifically the participants were asked to lose percentage wise or what specific methodologies were used to achieve weight loss. Body mass on average between the 2 tests went from 77.16 kg +/- 11.94 kg to 71.58 kg +/- 11.1 kg. Between the two tests, performance on the isometric handgrip strength test and isometric back strength test were indicated to be significantly decreased due to the coefficient of interclass correlation which were measured at 95.9 for the isometric handgrip strength test and 97.9 for isometric back strength. According to research by Koo and Li (2016), interclass correlation coefficients above 0.90 are considered to be of excellent reliability and therefore results of the study by Jlid et al. (2013) are said to be reliable.

Kraemer et al. (2001) studied the effects of rapid weight loss and a typical wrestling tournament schedule has on physical performance measures. The physical performance measures that were studied were maximal isometric grip strength via a handheld dynamometer. Lower body power via a vertical jump test conducted on a force plate. Hip and back strength via a hip and back dynamometer. Isometric upper body pull strength via a “bear hug” test, and finally, isokinetic tests to measure limb velocity concentric strength of the dominant upper and lower limbs via a isokinetic dynamometer. 12 athletes from the Penn State University wrestling team were recruited to be the participants in this study. 2 baseline tests were performed. One test was done in the morning and the other test was conducted in the evening. This occurred over a period of 2 days before the 1-week weight loss period commenced. During the period of rapid weight loss, athletes were instructed to lose approximately 6% of their body weight over the course of the week. After the week period, an official weigh in was done. 12 hours after the official weigh-in, the first match of the 2-day competition was scheduled to take place. At the weigh in after the weeklong weight loss period, the reported weight loss ranged from 4.63% to 6.75%. It was found that on average, given the 12-hour period between the weigh in and the first match of the tournament, the athletes were only able to put back on 1.8% of their body weight. Body weight did not return to baseline throughout the entirety of the 2-day tournament. An allowance of 2% of body weight from the first weigh in was given to the athletes which led the athletes to need to restrict calories and fluid intake once again to make weight in the morning on the second day of the competition. The first day of competition consisted of 3 matches and the second day consisted of 2 matches. Performance testing was done at the beginning and end of each match for both days. A test unique to this study to measure isometric upper body pull strength was the "bear hug" test. A strain gauge was inserted inside an adjustable padded board. Using a hand configuration that was both comfortable to the athlete and a grip the athlete usually used when executing a throw, they were instructed to take hold of the pad and squeeze maximally for 6 seconds. The data from the test was recorded via an isometric strength testing computer. The hand grip dynamometer and the hip and back dynamometer tests conducted to assess isometric hand grip strength and hip and back isometric strength were conducted in relatively the same manner. The difference being between the three was the machine and mode of physical performance each individual test was assessing. Vertical jump was also assessed. Each test listed had 3 attempts, with the best attempt from each test being recorded. Isokinetic strength tests were conducted on an isokinetic dynamometer for both the dominant knee extension and flexion velocities as well as the dominant elbow flexion and extension velocities. 2 limb velocity speeds were used (1.05 rad$\cdot$s^{-1} and 5.24 rad$\cdot$s^{-1}) with the knee extensors being tested at a 45° angle and the elbow flexors being tested at a 90° angle. 3 attempts were given with peak torque being determined to be the highest of the 3 attempts. Results of the study showed that isometric grip strength, isokinetic knee flexion torque (both slow and fast), isokinetic elbow extension torque (slow), and isokinetic knee extension torque (fast) were negatively affected.

Marttinen et al. (2011) studied the effects of subject-selected rapid weight loss methods on performance in collegiate wrestlers. 16 male participants who competed at a Division 1 collegiate level participated in the study. Athletes completed 3 months of specific wrestling training which consisted of aerobic work, resistance training exercises and wrestling specific drills before participating in the study. Athletes could self-select methods of rapid weight loss. They were not allowed to utilize certain rapid weight loss methodologies (as enforced by the NCAA) such as saunas, rubber suits, and diuretics. 4 tests were completed. 10 days prior to competition, 6 days prior to competition, 2 days prior to competition, and the day of the competition. At the end of the rapid weight loss period, participants competed in an intrasquad wrestling match, which was officiated and treated like a competitive match. A baseline level of performance was collected 10 days prior to competition. Performance measures included a handgrip isometric strength test using a dynamometer and a 30 second Wingate test. The maximal isometric strength tests consisted of 3 max effort attempts with 1 minute of rest in between each effort. The highest scoring effort was recorded. The 30 second Wingate test was performed on a lower body ergometer against 9.5% of the athlete's initial body mass. Measures of peak power, mean power, total work, and fatigue index were recorded at instantaneous 1 second intervals throughout the duration of the test. Participants who participated in the study lost between 0.0-8.1% of total body mass using self-selected methods. Most of the weight lost occurred anywhere from between 2 days before the competition, up to the day of the competition. Results indicated that across time, no significant differences or changes were observed in grip strength or Wingate test performance.

Mckenna and Gillum (2017) studied the effects of dehydration and rapid weight loss upon anaerobic power in collegiate wrestlers. In addition to examining the effects of rapid weight loss on anaerobic power, the study also looked to assess rehydration methods using a glycerol solution as opposed to just regular water. A total of 7 participants who competed in Division II wrestling in the NCAA participated in the study. Participants completed both an experimental and control trial. The experimental and control protocol called for the participants to run on a treadmill at 70% of their VO_2 max in a heated room until approximately 3% of body weight was lost. The control group following the dehydration protocol were given strictly water to rehydrate and the experimental group was given a glycerol solution to rehydrate. Both groups were given an hour total to drink the fluids given to them. To determine 70% of the VO_2 max, participants completed a familiarization trial in which aerobic capacity was tested. Subjects also gained an understanding of the tests they would complete to assess anaerobic power. A 30 second Wingate test for the lower limbs was chosen as the method of assessment for observing if anaerobic power was affected by dehydration of 3% of body mass. Results showed no significant decrease or difference in mean wattage between control or experimental groups.

Out of the included research in this section, maximal isometric grip strength via a hand grip dynamometer was included in 3 out of the 4 studies cited. The importance of assessing this measure in wrestlers has been covered. According to Chaabene et al. (2017) isometric strength is critical for upper and lower body holds and is the main means for which a wrestler is able to control his/ her opponent and is a major determining factor in upper-level success. Any negative effect experienced by wrestlers on this measure of performance due to rapid weight loss could prove detrimental to the success experienced in competition.

Martinnen et al. (2011) as well as McKenna and Gillum (2017) assessed lower body power via the Wingate assessment for a duration of 30 seconds. The typical/average duration of an explosive or anaerobic activity within a wrestling match is difficult to quantify. Nilsson et al. (2002) determined after examining athletes at the 1998 Greco-Roman wrestling world championships that the work-to-rest ratio of a match there was approximately 2 or 5:1 or approximately 37 seconds of work to 14 seconds of rest with the average match length being measured at 7 minutes. Nilsson et al. (2002) concluded that not only could anaerobic metabolic processes potentially be favored than aerobic metabolic systems, but that due to the determined work-to-rest ratio, those periods of rest helped to facilitate higher intensity actions within the match. This information on work-to-rest ratios potentially validates the choice of a 30 second Wingate test in determining anaerobic power output performance in wrestlers for future research.

Effects in performance measures in Taekwondo athletes

As described by Bridge et al. (2014), Taekwondo is a sport that is characterized by brief attacking periods lasting between 1 to 5 seconds with work to rest ratios ranging from 1:2 up to 1:7 sometimes in various other styles of Taekwondo. Matches, as also described by Bridge et al. (2014), under the World Taekwondo Federation (WTF) rules, are broken up into 3 2-minute rounds with one minute rest in between rounds. The objective of each match is to either outscore the opponent via landing a combination of directed attacks of kicks and punches to different areas of the opponent’s body, with each area scoring differently. Or, the match is concluded via a technical knockout (TKO). Taekwondo, being a combat sport, has various weight classes in which athletes can compete, both in male and female competition. With the presence of weight classes, the potential for prevalence of rapid weight loss occurring in the sport is there. This assumption has led to research which has examined the prevalence of rapid weight loss in Taekwondo. According to da Silva Santos et al. (2016) of approximately 72 Taekwondo athletes surveyed in their study which examined the prevalence of rapid weight loss, 77.4% of the regional and state level competitors surveyed, and 75.6% of the national and international competitors surveyed in the study utilized rapid weight loss. Currently, the WTF do have procedures in place, similar to that of the IJF. Weigh-ins take place the day before the competition, followed by on the morning of the competition, a random weigh-in test. These random weigh-ins have a 5% allowance, meaning that competitors on the morning of the competition cannot weigh-in more than 5% of their registered weight class (World Taekwondo Federation, 2019). This means there is still leniency and a potential for athletes competing in Taekwondo to cut weight, at least potentially up to 5%. Therefore, it is relevant to discuss research which has been conducted over the past 20 years that has looked at the relationship between rapid weight loss and the physical performance effects in Taekwondo.

Yang et al. (2014) studied the effects on physical performance in taekwondo athletes between both gradual and rapid weight reduction. 10 participants participated in the study which was comprised of 2 phases. A rapid weight reduction phase and a gradual weight reduction phase. Over the course of the 2 phases, a total of 8 testing days were conducted. Both phases (rapid weight loss phase and gradual weight loss phase) began with a 3 week initial baseline period. The beginning of this period consisted of collecting anthropometric data, physical performance data (via vertical jump assessment using a squat jump and countermovement jump and a taekwondo specific performance test), blood samples and psychological data. At the end of the baseline period, a taekwondo specific performance test was the only physical performance test conducted. The taekwondo specific test was used to assess anaerobic performance via lactate production rate and kick frequency. The test consisted of the athlete throwing specific kicks at a strike protector which measured kick frequency. Kick frequency was also measured by an investigator. A warm-up was conducted, and blood was taken from the earlobe to determine a resting lactate level. Once testing began after the warm-up, a 5 second maximal load was performed by the athlete and a 3-minute rest followed. By maximal load, what is being referred to is a series of kicks which were to be performed by the subject. Following the 3-minute rest, blood was taken again to determine lactate levels. At the end of the 3-minute rest, 6 maximal loads (each of which lasted 5 seconds) were performed and were interspersed with 10 second rest intervals. Blood was taken 2, 4, 6, 8, and 10 minutes after the series of maximal loading to determine blood lactate levels. To determine lactate production rate, the formula highest lactate – 2nd resting lactate/20 was used. The taekwondo specific performance test was done all 8 testing days. The vertical jump assessments were only done at the first baseline test and at the immediate conclusion of each weight reduction period. The vertical jump assessments were done on a force plate and participants were given 3 attempts for both the squat jump and the countermovement jump. The best height was recorded. After baseline tests were done (3 weeks long), participants were asked to reduce their body mass by 5% within 4 days. This period was the rapid weight loss phase of the experimental period. Participants could reduce body mass using whichever method they usually employed to lose body mass for competitions in the past. At the conclusion of the rapid weight loss period, athletes weighed in and then had their competition day. A weeklong recovery period was given to the athletes following the rapid weight loss phase. Then the gradual weight loss phase was commenced. The difference between the gradual weight loss phase and the rapid weight loss phase is the length of time given to the athletes to reduce 5% of their body weight as well as the methods in which the athletes used to reduce body weight. This period of testing still consisted of a 3-week baseline period, the beginning and end of which had testing conducted. 4 weeks instead of 4 days were given to the athletes this time to lose the requested amount of body weight. The methods employed by the athletes to achieve this was by combining exercise with a restrictive diet protocol that called for minimal caloric intake. Following the conclusion of the period of gradual weight reduction, a weigh in was done followed up by a competition day. Results of the vertical jump assessments showed a significantly higher result between the end of the rapid weight reduction period than at the beginning of the baseline period. The mean squat jump measurements were 40.9 cm at the beginning baseline test and 42.3 cm post rapid weight reduction test. Mean countermovement jump measurements were also different. At the beginning baseline test the recorded average was 43.1 cm and 44.1 cm at the end of the rapid weight reduction period. When kick frequency was compared between the 2 phases of weight reduction, kick frequency was measured to be higher in the tests done on the day of weigh-in and on competition day by both the investigator and the electronic protector during the gradual weight reduction phase as opposed to the rapid weight reduction phase.

Yang, Heine, and Oliver (2018) looked to examine rapid weight loss and its effect on Taekwondo performance. This study included 5 participants, all of whom were black belts in

Taekwondo. The study consisted of a control period and a period of rapid weight loss. Participants during the rapid weight loss period were asked to lose approximately 5% of their body mass in a period of 3.5 days. During the control period, participants were asked to not lose any body mass and keep their weight consistent. This was the only difference present between the two periods. Each period lasted the same amount of time. In between the control phase and the rapid weight loss phase were 2 days of recovery. Each phase comprised of a pre-test weigh in, weigh in after 3.5 days, and a competition day weigh in. Following the second weigh-in, a 16-hour recovery period was allotted to the participants to mimic how a typical Taekwondo competition is conducted. To assess performance, on competition day, the athletes competed in 3 simulated matches against sparring partners (who were not participants in the study) with a 1-hour break in between matches. A gas analyzer was used and placed on the back of the athlete during competition to collect data. This device was not allowed to be struck by the opponents of the participants. VO_2 information was gathered using a portable spirometric device which measured oxygen concentration through an electrochemical sensor breath by breath. The study also sought to consider which energy systems were primarily being used by analyzing oxygen consumption, blood lactate levels, and EPOC levels immediately following exercise. Results showed the VO_2 mean was significantly higher in the RWL group during the 3rd match when compared to the control. VO_2 peak and absolute VO_2 peak were significantly higher in the RWL group in the 2nd and 3rd matches when compared to the control group. This data which was reported back was explained by Yang et al. (2018). Kick frequency was measured as well during the simulated matches using time motion analysis. The reported kick frequency was higher in the RWL testing period as opposed to during the control testing period. Yang et al. (2018) concluded that this higher kick frequency explains the higher measured VO_2 levels and discrepancies between the control tests and the RWL tests. It was also determined that the aerobic system was the predominant system at work during the simulated matches through calculation using the subject's VO_2 levels at resting and subtracting those levels from the VO_2 measured in a round.

The study of a particular note that was included in this section is the study conducted by Yang et al. (2014) comparing the differences in performance measures when participants used either gradual and/or rapid weight loss to lose weight. While during the rapid weight loss trial, there was a measured significant improvement in both the standing jump and countermovement jump tests only following the rapid weight loss trial. There was also a noticed improvement in kick-frequency only following the gradual weight loss trial and not the rapid weight loss trial. Yang et al. (2014) explained that this could be a result of 2 things occurring. A potential learning effect had occurred due to the rapid weight loss trial occurring before the gradual weight loss period (the same participants were used for both trials). The other offered explanation was that potentially during the gradual weight loss trial, the participants were in better physical condition compared to when they were undergoing the rapid weight loss trial. The results found by Yang et al. (2014) would seem to go along and support the recommendations made by Franchini et al. (2012) that gradual weight loss rather than rapid weight loss should be the method in which athletes adjust weight before a bout or competition. Research which examines and compares the effect gradual weight loss has on performance measures as opposed to rapid weight loss, should be continued to be explored.

Effects on performance measures in boxers

Along with wrestling, the sport of boxing has long been established in cultures across generations of people, with the first reported involvement in the Olympic games being dated as far back to 688 B.C. (Chaabène et al., 2015). The sport has had major changes to it since then. One being the advent of weight classes in 1867 (Smith, 2006). The other major change was the establishment of a set time period in which the bouts would last (Smith, 2006). With the establishment of rounds and a set time period, Smith (2006) has pointed out that this shifted the energy demands of the body during a boxing match over from more predominately aerobic sources, given that bouts before this rule were no time limit matches, to the body needing to rely more so on anaerobic sources. While the period of time in which the first reported implementation of weight classes within the sport of boxing came to be is not in question, the history of weight manipulation and rapid weight loss in boxing is difficult to trace. However, the presence of rapid weight loss in boxing is present though. Smith (2006) concluded through the compilation of data and research over a 17-year time period spanning from 1987 to 2004, that senior level amateur England boxers lost on average of between 6.0 to 8.3% of their body weight over the course of a 21 day pre-contest period. This was done by combining both a gradual and rapid weight loss approach. This was observed in boxers across all weight categories excluding super-heavyweights. Smith (2006) also found that during the rapid weight loss phase (final 7 days of the 21-day period), athletes lost approximately 5.2% of their body via fluid manipulation. Rapid weight loss is well and truly apart of boxing however with the presence of an abundance of weight classes in boxing, the magnitude of rapid weight loss in which athletes undergo seems to be far less than that of MMA for instance. Below is a presentation of the research in which has examined the physical performance effects of rapid weight loss among boxers over the past 20 years.

Hall et al. (2001) studied the effects of rapid weight loss on performance and mood in amateur boxers. This study involved 16 participants, all of whom had at least 2 years of competitive experience with the mean competitive experience being 5. All participants ranged from flyweight to heavyweight in their respective classified competitive weights. The athletes who participated in the study were all tested a total of 3 times with physical performance testing occurring only on 2 of those 3 testing days. The first day of testing consisted of only an interview with the athletes to garner their opinions and views of rapid weight loss and their personal experience with it. Participants also during the first testing day, provided information and feedback to help develop an adequate performance task in which they felt would accurately assess boxing performance. The performance test time frame was decided on being 4 sets (rounds) of 2 minutes each with 1-minute recovery in between sets (rounds). This time frame was decided on because it was the same duration as a typical amateur boxing bout. The performance test was burpees and press-ups done continuously for the duration of the 2-minute rounds. To judge the success of individual performance during the test, the participants told the investigator who was observing the performance, the number of reps they predicted they could achieve for each performance test in its entirety. The target number set by the athlete initially was subtracted from the actual number of reps performed by the athlete. If the number found from doing that calculation was positive, it indicated that the athletes were successful in completion of the task. If the number was negative, that meant the athlete fell short of their completion of the task. The athletes who signed up for the study agreed upon losing a certain amount of weight in one week. The subject population was evenly split into 8 and 8. One group of 8 would perform the performance test after they had done rapid weight loss and had reached the goal weight set by the investigators (experimental group). The other group of 8 would perform the performance test the same week without undergoing rapid weight loss (control group). The order was reversed for the second and final test. The group of athletes who did not undergo rapid weight loss during the first test now had to get down to the agreed upon weight as dictated to them by the investigators. The group who had performed rapid weight loss for the first test had a week to recover and would perform the second test at their normal weight. Once the participants had weighed-in for the test, they were given approximately 2 hours in between weighing in and the start of the performance test to try and rehydrate and recover from the weight cut. This mimicked the time normally allotted to the athletes in an amateur boxing bout. Results of the study showed that the participants cut an average of 5.16% to participate in the tests. Results of the study also found that the participants' expected performance was not met once they had undergone rapid weight loss and performed the performance test at their championship weight (mean goal repetitions: 300.33 compared to mean actual performance repetitions: 289.27). The participants had underperformed and not met the initial predicted goal set out by them in the pre-test interview.

Zubac et al. (2019) studied the effects of rapid weight loss on neuromuscular performance in boxers. A total of 9 athletes completed the study. The mean average competitive experience was approximately 5 years with a minimum of 3 years in weight loss experience. The group of nine athletes were split into two groups (control and experimental) following a period (1 week) of familiarization. The group of athletes who were in the control group, were asked to maintain their body weight while the experimental group were asked to cut approximately 3% of their body weight within a 3-day time period before participation in the experimental protocol. After experimentation in the first group was completed, the control group of athletes then became the experimental group and the experimental group who had completed the rapid weight loss trial then became the control group. A 2-week period of rest between testing was mandated as a wash-out period. The familiarization period the athletes underwent assessed baseline levels of resting heart rate, height, mass, and body fat. For the later neuromuscular performance test which followed the familiarization period, 70% of maximal voluntary contraction effort of the knee extensors had to be determined. The athletes were requested to perform brief maximal voluntary contractions of the knee extensors and to develop as much force in the shortest amount of time they could and sustain the contraction for 5 seconds. This maximal force generated allowed researchers to determine 70% of that effort for later use in the experimental protocol. The experimental protocol went as followed. Tests were done on a dynamometer with the dominant knee positioned at 60° of flexion. Electrodes were placed upon the knee extensor muscles because the test involved interpolated twitch technique to assess neuromuscular function. After a warm up of 3 isometric contractions at 25, 50, and 75% effort, each of which lasted 5 seconds, athletes then performed 1 set of 3 maximal (100%) voluntary contractions. These lasted 5 seconds each with 60 seconds of rest in-between each contraction. During the 60 second rest, interpolated twitch technique was used. A doublet of 100 Hz was superimposed, and a control doublet of 5 seconds was delivered 5 seconds immediately following contraction. The greatest maximal voluntary contraction was selected and recorded as MVC1 for later analysis and comparison. Following the maximal voluntary contractions, high frequency fatigue impulses and low frequency fatigue impulses were delivered to the knee extensors before the athlete proceeded to the fatigue protocol. The fatigue protocol asked the athletes to sustain a contraction against 70% of their maximal voluntary contraction effort (determined in the familiarization period) which determined the athlete’s exhaustion threshold. Once the athlete could not maintain the force required to hold 70% of their max, the test was over. A final post fatigue protocol was the final part of the experimental protocol. A final 5 second maximal voluntary contraction (labeled MVC2 for later analysis and comparison) was superimposed and a control impulse was delivered to the muscle 5 seconds post contraction followed by high and low frequency fatigue impulses. On Appendix B is a visual representation presented by Zubac et al. (2019) detailing the neuromuscular assessment protocol used in the study.

Results of the brief maximal voluntary contractions (MVC1) which were performed in the beginning of the experimental protocol showed a significantly lower force production (approximately 12%) than results of the control tests. Time to exhaustion was shorter by 16 seconds during the fatigue protocol for the rapid weight loss tests when compared to the control tests. Voluntary activation of the knee extensors decreased by approximately 7% in the rapid weight loss tests when compared to the control tests.

As seen with Hall et al. (2001), attempts have been made to create a more sport specific boxing performance task to assess physical performance. It was determined in an interview with boxers during this study by Hall et al. (2001), that a circuit training task was considered the best judge of performance because the quality of work could not be controlled. There is an issue present if performance quality was based off, for instance shadow boxing, bag work, or sparring. If number of punches thrown in a round was decided to be the tool in which performance was measured to be good or not, boxers interviewed by Hall et al. (2001) indicated that they could throw punches at reduced power in order to achieve a higher score thus leaving room for error. Sport specific performance testing measures should still be pursued and developed for the sport of boxing.

Effects on performance measures in multiple disciplines

Mendes et al. (2013) performed a study which looked to examine the effect of rapid weight loss on high intensity performance. This study also looked to examine whether prior experience to rapid weight loss may have any sort of buffering effect on physical performance decrements. 18 total participants completed the study. Participants came from multiple disciplines including judo, mixed martial arts, wrestling, and jiu-jitsu. Participants were separated into 2 categories. A weight cycling group and a non-weight cycling group. 8 athletes comprised the non-weight cycling group, and 10 comprised the weight cycling group. To be classified in the weight cycling group you had to meet a certain criterion. Athletes must have cut weight by more than 4% multiple times for 2 consecutive seasons. Non-weight cyclers must not have cut their body weight by more than 2% on any occasion during the past 2 seasons. A familiarization session preceded the initial weigh in and performance testing to start the experimental period. Following the initial test, the participants in the weight cycling group had no more than 5 days to lose 5% of their body mass using the methodologies they normally used to make weight before a competition. Food intake as well as water consumption for the last 3 days was logged and tracked. Performance testing consisted of 8 sets of a 15 second maximal intensity arm crank exercise which was measured on an upper body ergometer. Each set had a 20 second passive recovery bout. The machine was loaded to 4% of baseline body mass. Athletes on the second day of testing weighed in to confirm that the participants did achieve a 5% loss in body mass. Prior to retesting performance on the second day, athletes had 4 hours to rehydrate and eat food as they normally would following a weigh in before a competition. Results of the study showed that despite a 5% weight cut, given a subsequent 4-hour recovery before testing, no effect was shown in performance. Mean power, peak power, and total work performed remained unaffected.

Research by Pallarés et al. (2016) sought to study strength and power output levels of Olympic combat sports athletes who were at varying degrees and levels of hypohydration. 163

participants (124 male and 39 female) were studied. 76 of the participants were wrestlers, 62 of the participants were taekwondo athletes, and 25 of the participants were boxers. Approximately 61.7% of the 163 athletes studied competed previously at the 2013 Spanish National Championships. Testing of neuromuscular performance occurred at two different times. Once, between 60 and 5 minutes before official weigh-in for the athlete's national championship. The second test occurred between 60 and 5 minutes before the beginning of the first combat bout the following day after weigh in. Neuromuscular performance was tested via measuring bar displacement velocity against 3 to 5 incremental loads in the bench press, an isometric hand grip strength test, and a countermovement jump test for height. Bar displacement velocity was measured using a linear encoder attached to a Smith machine to determine muscle velocity. Weight was added on in increments after a warm-up was completed until a mean propulsive velocity between $0.60 \text{ m} \cdot \text{s}^{-1}$ and $0.50 \text{ m} \cdot \text{s}^{-1}$ was met. This threshold was usually met somewhere between 3 to 5 increasing loads into the test. Mean propulsive velocity was calculated by taking the average velocity measured only during a portion of the concentric phase of the lift where the bar acceleration was greater than that of the acceleration of gravity. In each trial, three repetitions were completed at a light load, 2 repetitions were completed at a medium load, and only one repetition was completed at a heavy load. Those loads were predetermined by measuring the mean propulsive velocity of each lift done by the athlete and determining if the measured results fell between a measured and calculated predetermined range. Lower body power was measured via a countermovement jump. This required the athlete to keep their hands on their hips for the entirety of the jump. The athlete performed 3 jumps. For each jump, flight times were recorded and the average of the three jump times was the result. Maximal isometric handgrip strength was measured via a dynamometer using both dominant and non-dominant hands. Following hydration measurements (urine osmolality test) prior to weigh-ins during the first testing day, athletes were split into 3 categories. The three categories were. those who were euhydrated, hypohydrated, and severely hypohydrated. Following the first day of testing before the weigh-ins, athletes had 13 to 18 hours to hydrate themselves before their first competitive match and the second day of testing. The mean body mass changes measured for each group was less than 1% for euhydrated athletes, 1.2% for hypohydrated athletes, and 3.1% for severely hypohydrated athletes. Results of the neuromuscular performance tests showed an increase in mean propulsive velocity in the bench press in the severely hypohyrated group compared to the euhydrated group and the hypohyrdated group and a significantly higher lower body power increase (countermovement jump test) for the severely hypohydrated athletes when compared to the euhydrated athletes. No significant differences between hydration states were detected in the isometric handgrip strength test were reported.

A study by Timpmann et al. (2008) studied how self-selected rapid weight loss methods affected combat sports athletes through measured muscle performance tests. 17 participants participated in the study. 12 of the participants were wrestlers and 5 of the participants were karetekas. All athletes who were participating in the in the study were experienced in rapid weight loss. Participants reported on the first day of the experimental period to perform baseline tests in muscle performance prior to any of the participants undergoing any rapid weight loss. After baseline measures were obtained, participants were asked to lose approximately 5% of their body mass within 3 days of initial testing. Athletes could self-select which methods they would use to accomplish this goal, but they were asked to abstain from pharmacological means such as diuretics or diet pills. Muscle performance was measured by using peak torque tests and a muscular endurance test. Peak torque was analyzed using an isokinetic dynamometer using the knee extensor muscles. 3 maximal knee extensions were done at each different angular velocity on the dynamometer. 10 second rests were given in between each individual maximal velocity attempt followed by a 1-minute rest in between each maximal velocity set. The best result of each set was recorded. Following a 5-minute rest, a muscular endurance test was done on the same isokinetic dynamometer test. The test for muscular endurance was devised to mimic the demand required of the individual during their respective combat sport. Submaximal knee extensions were done at a given angular velocity for 45 seconds at a given rate. This was succeeded immediately by 15 seconds of maximal effort contractions with the total time of the trial being 3 minutes long. Total work, maximal work, and submaximal work were all quantities and values used to assess and quantify the performance of the athletes. A period of familiarization with the tests one week before the experimental period began was done to minimize error in final data due to unfamiliarity with the tests in the athletes. Comparisons of the performance tests done on day 1 versus on day 4 following a period of rapid weight loss showed that peak torque following rapid weight loss in the athletes at two different angular velocities was significantly lower in day 4 than in day 1. Also, while submaximal work and maximal effort work was not significantly affected between the 4 days of testing, total work when compared between day 1 and day 4 weas significantly reduced by comparison.

Performance effects from unspecified disciplines

A study by Barley, Chapman, Blazevich, and Abbiss (2018) sought to study neuromuscular performance in combat sports athletes following a dehydration protocol. 14 participants were used. Athletes had a familiarization session in which they were introduced to the tests they would be undergoing in the two experimental sessions they would be taking part in.

The study consisted of a control protocol and a dehydration protocol. In the dehydration protocol, participants would be exposed to 3 hours of passive heat exposure to illicit a dehydration response. The goal was for the participants to lose approximately 3 to 4% in body weight. Passive heat exposure occurred in an environmentally controlled chamber at 40°C and 63% relative humidity. Participants wore a plastic suit and were not allowed to consume fluids for the duration of the exposure. The control protocol consisted of 3 hours of thermoneutral exposure which consisted of exposure to an environment kept at 23.5°C at approximately 50% relative humidity with participants allowed to drink water throughout the duration of the 3-hour protocol with the aim of preserving body mass. Neuromuscular function was assessed using a maximal voluntary isometric knee extension contraction protocol. This was before the dehydration or control protocol and after a fatiguing knee extensor protocol had been administered 3 hours after the control and dehydration protocols had ceased. The maximal voluntary contraction protocol consisted of 6 maximal voluntary isometric contractions, 3 of which were done in less than 2 seconds with the athletes instructed to do them as fast as possible while the final 3 contractions were done and held for slightly longer at between 3 to 5 seconds. During those contractions, participants were instructed to contract the knee extensor muscles as quickly and as forcefully as they possibly could with a 30 second rest in between efforts. An electrical stimulus was administered during the 3 longer contractions to assess muscle voluntary activation. The neuromuscular performance test was administered using an isokinetic dynamometer machine. To determine 85% of the subject's maximal voluntary isometric contraction, before testing began, participants performed a warm-up of 8 voluntary knee extensions at approximately 30% of their perceived maximal voluntary contraction and the percentage was progressed. This progression occurred until the athletes reached 100% of their perceived maximal voluntary contraction. 85% of the maximal isometric contraction was determined after that. A 2-minute rest was given after this was completed before the actual testing began. Rate of force development was determined by taking the first 75 milliseconds of each maximal voluntary isometric contraction due to a high rate of neural activation being present in the first 75 milliseconds of a maximal voluntary isometric contraction. The fatiguing protocol consisted of repeated maximal voluntary isometric contractions of 5 seconds using 85% of their established baseline with 5 seconds of recovery in between contractions. Athletes went until failure, which was established to be when the athlete failed to reach a predetermined torque in two consecutive contractions. During all the contractions, surface EMG data was collected. Electrical stimulation was also administered to determine the maximal M-wave amplitude and excitation-coupling efficiency was done before and 3 hours after the dehydration and control protocols were administered. Excitation-coupling was also found following the fatiguing protocol as well. The results of the study showed no significant difference was experienced for measured maximal voluntary isometric contraction torque. However, fewer contractions were completed during the fatiguing protocol following the dehydration protocol as opposed to following the control protocol.

Kurylas, Chycki, and Zając (2019) studied the effects of hydration status on anaerobic power in combat sports athletes. 6 participants who were international level competitors in an unspecified combat sport participated in the study. All competitors were competing in the middleweight division (154-160 lbs). Athletes were tested a total of 4 times over the course of the 29 day experimental period. The first test occurred 4 weeks prior to competition day. The second test occurred 2 weeks prior to competition day. The third test occurred 1 day before the competition day. The fourth and final test occurred on the day of the competition. Urine samples to assess hydration via urine osmolality were taken at each test day. Anaerobic performance was also assessed each of the 4 test days using a 30 second upper body Wingate test. Variables collected through the test were peak power, mean power, and total work. Significant differences were found in the data via ANOVA analysis in peak power between 1 day before competition and on the day of the competition (mean peak power 1 day before was measured and calculated at 672.43 W and on competition day mean peak power levels were measured and calculated at 924.24 W). Statistically significant differences were also observed in mean power (1 day prior to competition mean power was measured and calculated to be 397.00 W and on competition day, mean power was measured and calculated to be 460.70 W), and total work (1 day prior to competition, the mean calculated value of total work equaled 10393.60 J as opposed to on competition day where it equaled 13271.60 J). Urine osmolality was measured at significantly higher levels between 1 day before the competition and between 4 weeks and 2 weeks before competition.

RESULTS

When looking at the research examining the physical performance effects of rapid weight loss among combat sports athletes, negative effects data is presented in Appendix I. Negative effects were observed in isometric strength (Barley et al., 2018; Alves et al., 2018, Isaaco et al., 2019; Kraemer et al., 2001), isokinetic strength (Timpmann et al., 2008; Kraemer et al., 2001), upper body power (Barley et al., 2018; Kurylas et al., 2019), muscular endurance/time to fatigue (Barley et al., 2018; Zubac et al., 2019), neuromuscular function (Zubac et al., 2019) and sport specific tasks (Koral & Dosseville, 2009; Hall et al., 2001). Research also showed no effect in isometric strength (Camarço et al., 2016; Pallarés et al., 2016; Marttinen et al., 2011; Jlid et al., 2013; Morales et al., 2018), lower body power (Koral & Dosseville, 2009; McKenna & Gillum, 2017; Marttinen et al., 2011), upper body power (Mendes et al., 2013; Artioli et al., 2010), neuromuscular function (Barley et al., 2018), and sport specific tasks (Yang et al., 2018; Artioli, Iglesias, et al., 2010). Given the split nature of the research over the past 20 years, conclusive statements regarding whether RWL has an impact on performance within the context of combat sports is somewhat difficult. However, whether RWL has a negative impact on performance is not in question given some of the results presented in the research. What is rather difficult is at what percentage of body mass loss do the effects from RWL start to become unquestionable and start to unequivocally affect physical performance. The magnitude of potential performance effects seems to depend on factors which include methodologies used for achieving rapid weight loss (active vs. passive weight loss), the recovery time in between the conclusion of the rapid weight loss period and the actual match/competition itself, the magnitude and amount of weight the athlete loses in a given time, and the length of time given to the athlete to lose the weight. It seems a combination of gradual and rapid weight loss may benefit the athlete in terms of not affecting performance (Morales et al., 2018; Yang et al., 2018), and recommendations have been made by Franchini et al. (2012) which encouraged gradual weight loss as the preferred method of weight adjustment in athletes as opposed to rapid weight loss to avoid potential performance effects. This however is context dependent. While a combined approach is the preferred way of losing weight to minimize performance effects, some organizations give fighters the opportunity to fight on short notice. Short notice in this context meaning competing with less than 2 weeks' notice. There are instances of fighters cutting 20 pounds on 6 days' notice such as Jorge Masvidal in a recent title fight opportunity against Kamaru Usman at UFC 251 which took place on July 11th, 2020 (Masvidal, 2020). The majority of the weight lost came from saunas, fluid restriction, caloric restriction, and fluid loss. This is an instance in which gradual weight loss was not an option, therefore the fighter must resort to a more rapid means.

According to Mendes et al. (2013), it appears as though regardless of experience with rapid weight loss procedures, there was no difference in measured performance between experienced and non-experienced weight cyclers following a moderate weight reduction of approximately 5%. While there may not have been any indications of any biological adaptations which prove advantageous from chronic rapid weight loss, experience can play a role in an athlete's decision-making before the weight cut, during the weight cut, and most importantly, during the recovery period following the weight cut. This time period and what the athlete does following weigh-in could prove crucial. This time period seems to determine whether or not an athlete will be able to return to baseline levels of performance before initiating the weight cut (Mendes et al., 2013). Experienced athletes during this process will have an idea of what to expect during the process of rapid weight loss and have a better understanding of timing and when to cut the weight and, perhaps, which method of rapid weight loss may or may not effect their performance.

DISCUSSION

Looking forward to future research, there are some areas and considerations that may be of benefit to be looked at and addressed further. This may help to refine the data and possibly help to draw better conclusions on the physical performance effects associated with rapid weight loss in combat sports athletics.

Areas for Future Study and Considerations

Length of time given for recovery following rapid weight loss

Research on physical performance effects in combat sports athletes following a period of rapid weight loss finds there are still measured performance effects as far as 24 hours later following RWL (Barley et al., 2018, Alves et al., 2018). Some research however reports no physical performance effects in athletes after only a 4-hour recovery period (Artioli, Iglesias, et al., 2010, Mendes et al., 2013). Mendes et al. (2013) has concluded that adaptation to rapid weight loss is likely to not protect athletes from the potential negative performance effects experienced but rather placed an emphasis on the recovery period in between when the athlete weighs in and when the bout takes place. More specifically, the food and fluid intake in which the athlete consumes during that time period is arguably the most crucial aspect for mitigating those potential performance effects. Given the range of magnitudes of rapid weight loss reported by combat sports athletes in studies such as by Artioli, Gulano, et al. (2010), length of time needed to recover following a period of rapid weight loss seems to be not only dependent on the recovery time in between weigh-in and the bout itself but also possibly the magnitude of weight in which that athlete has lost. Potentially, the more weight lost by an athlete, the greater amount of time will be needed for the athlete to fully recover and get back to baseline measurements.

Future research should be conducted which examines the effects of different lengths of recovery periods following different magnitudes of dehydration to potentially guide coaches and athletes in the future of generally how long it takes an athlete to recover. This could lead to potentially a development of a formula or standardized weight lost calculation given the total body weight lost and time allotted to the athlete to recover following the weigh-in. However, each individual athlete is different, so a standardized calculation may not be plausible or reliable given natural human differences and different responses.

Physical Performance Effects of Rapid Weight Loss of Women in Combat Sports

Only 3 of the included studies which examined physical performance effects of rapid weight loss in combat sports athletes chose to include women as a part of their subject group (Pallarés et al., 2016; Koral and Dosseville, 2009; Morales et al., 2018). Given the measured and reported prevalence of rapid weight loss among women in combat sports (Artioli, Gulano, et al., 2010; da Silva Santos et al., 2016; Hillier et al., 2019), research in the future on the physical performance effects of rapid weight loss in combat sports should seek to examine the effects measured in women. The biological and physiological differences between men and women may lead to greater or lesser effects on performance at the same magnitude of weight lost during a period of RWL.

Methods used for achieving rapid weight loss

The methods in which athletes choose to achieve rapid weight loss and or which methodologies the researchers choose to have their participants use to induce rapid weight loss are of some importance to discuss as they relate to accuracy of assessing levels of dehydration achieved by the participants. Muñoz, McKenzie, and Armstrong (2014), found that biomarker testing accuracy and sensitivity can be influenced by which method (active or passive) of dehydration is chosen to be used. Different tests are better suited to detect changes in levels of dehydration depending upon which form of dehydration is used. Research in the future should be cognizant of which methodology their participants use or which methodology they choose to include in their dehydration protocols. This will allow in future studies when it comes time to testing levels of dehydration achieved, the ability to get the most accurate understanding of the actual level of dehydration achieved by the athletes being tested.

Another important factor which was noted by Savoie et al. (2015) in their meta-analysis was the potential effects of either a passive or active dehydration protocol had on muscle performance. When compared with a passive protocol such as saunas or hot water baths, an active dehydration protocol such as running on a treadmill or using a bicycle ergometer decreased muscle performance by an additional 4.8 ± 1.8 % which then increased to 4.9 ± 1.8 % once hypohydration level and type of muscle performance were corrected for. Depending on which attribute of physical performance is being measured may dictate the type of dehydration protocol which is used. This is an important factor to consider for athletes and coaches as well when considering cutting weight.

Sport specific performance testing

Sport specific performance testing as done by Yang, Heine, and Grau (2018) in Taekwondo athletes, Artioli, Gulano et al. (2010) in Judo athletes, Hall and Lane (2001) in boxers, and the "bear hug" test conducted by Kraemer et al. (2001), as well as Barley, Iredale, et al. (2018) in MMA athletes utilizing the repeat effort performance test should be implemented more as a way of testing the effects of rapid weight loss on sport performance. While tests such as Wingate test or a vertical jump test are able to assess singular specific performance measures like power output, assessments such as simulated matches set up and critiqued as they would be in a sanctioned event would give a better sense of the effect of rapid weight loss on performance as a whole. It is difficult to quantify how the results from a Wingate test for example would transfer over into competition. As pointed out by Bridge et al. (2014) for example, the Wingate test lacks mechanical specificity and does not mimic the anaerobic demands found in the sport of taekwondo. Cheuvront and Kenefick (2014) however, have highlighted the difficulties with this kind of testing modality. Test familiarization, tests that are not ecologically valid, and experience of the volunteers involved could all be limiting factors and factors which could contribute to the inconsistent results of studies which have chosen to examine the effects of dehydration on physical performance via a sport specific performance test.

Larger sample sizes

Most of the included studies over the past 20 years concerning the physical performance effects of rapid weight loss among combat sports athletes had sample sizes that were less than 20 participants. Given the nature of the research looking at the physical performance effects of rapid weight loss in combat sports athletes, some of the research required athletes who were experienced not only in rapid weight loss but also were proficient in their individual sport as well which dwindles down the initial pool of participants to draw from. This is a possible justification of the small sample sizes present in most studies. However, as explained by Faber and Fonseca (2014) the problem or danger with a small sample size is the tendency to assume true a false premise. Hackshaw (2008) also explained that issues with small sample sizes lie in the possible interpretation of the results and possibly over-estimating the magnitude of an association or lack thereof. Justification or an explanation as to why the sample sizes tested are as small as they are is limited among the research included in the review. Artioli, Iglesias, et al. (2010) acknowledged that because the study was done only in athletes who were experienced weight cyclers, results are not applicable to other judo populations. Studies also on whether previous weight cycling experience plays a role in recovery time following a period of rapid weight loss, which research done by Mendes et al. (2013) has found that chronic weight cycling more than likely does not protect the athlete from experiencing the negative impacts of rapid weight loss, however research should still be done to examine if this is the case or not.

Rehydration methods

Methods and documentation of the diet and beverages used for rehydration during the recovery period following rapid weight loss in combat sports athletes is also another area of research that should be examined. Looking at what beverages (type/amount/quantity etc.) and nutrition protocol are best to consume during the period of time in between weigh-in and competition may help better aid in the rehydration process and therefore lead to improved performance measures. McKenna et al. (2017) found rehydration via a glycerol solution in wrestlers following a period of rapid weight loss (3% body mass loss via dehydration) had no significant impact on anaerobic performance measures (however, the study also found no significant effect of rapid weight loss on anaerobic performance in general). A study done by Oopik et al. (2002) found that creatine supplementation following a period of rapid weight loss during the recovery period between weigh in and performance testing did not aid in restoration of body mass lost (4.5-5.3% reported body mass lost in 5 male participants), however isokinetic performance increased (W_{max}) by 19.2% between tests immediately following weigh-in and 17 hours later following supplementation with a glucose-creatine mixed beverage. Research on supplementation during the recovery period between weigh in and competition/testing the next day should be further investigated to see if physical performance measures are affected to a lesser extent following a period of rapid weight loss.

Larger magnitude of weight loss

Research included in this review examined weight loss of a moderate amount, typically of around 3 to 5% and its effect on physical performance measures. Examples of larger weight cuts are documented though and are a reality of certain sports. An example of this as mentioned in the results section included most recently Jorge Masvidal who cut approximately 10% of his body weight to make the 170-pound Welterweight limit in the UFC for a championship fight. Short notice fights occur and require sometimes the athletes to cut a large amount of weight in a very short window of time. These larger magnitude weight cuts should be examined and see what the effect on physical performance measures would be following a standard recovery period. However, a difficulty with doing these tests is getting approval from an IRB review board. Having a significant number of participants willingly lose more than 5% of their body mass via dehydration and studying the effects on physical performance is potentially dangerous for the participants' health and safety. To look at a larger magnitude of weight loss, case studies may be an avenue to do so.

CONCLUSION

The research on the physical performance effects of rapid weight loss among combat sports within the last 20 years is limited. Research has found both measured effects on performance aspects as well as no measured performance effects. These mixed results could be explained via differences in the dehydration protocols, length of time given to recover following a period of rapid weight loss, sample sizes, and differences in testing individual physical performance measures. Definitive statements on the effects rapid weight loss have on physical performance measurements among combat sports athletes are difficult to come to, however negative effects are clearly present in the research. The point in which rapid weight loss and the measured performance effects become unequivocally linked is still in question though. Further and continued research on the topic should continue to be conducted and analyzed to come to a better understanding of the practice and prevalence across the combat sport community.

APPENDIX A: RAPID WEIGHT LOSS QUESTIONNAIRE

Questionnaire about pre-competition rapid weight loss
Answer the questions with as much **attention** and **seriousness** as possible.
THE QUESTIONS REFERS TO RAPID WEIGHT LOSS IN ORDER TO COMPETE IN A GIVEN WEIGHT CLASS
The University of Sao Paulo thanks for your participation!

GENERAL INFORMATION. **Today's Date: _____/_____/_______.**

1. Age: ________ years.

2. Gender: ( ) male ( ) female

3. At what age did you begin to **practice** judo? ___________ years.

4. At what age did you begin to **compete** judo? ___________ years.

5. How much do you weight? ________ kg.

6. How tall are you? ________ m.

7. Please describe your achievements and participation in Judo competitions to date:

Regional or city level competition (*give some examples of regional or city level competitions*)
( ) participated without winning medal ( ) won a medal ( ) never participated

State level (*give some examples of state level competitions*)
( ) participated without winning medal ( ) won a medal ( ) never participated

National level (*give some examples of national level competitions*)
( ) participated without winning medal ( ) won a medal ( ) never participated

International level (*give some examples of international level competitions*)
( ) participated without winning medal ( ) won a medal ( ) never participated

8. How many times did you compete in the last year (including non-official competitions)?___________________.

9. In how many competitions did you win medal in the last year (including non-official competitions)?___________.

WEIGHT HISTORY AND DIET PATTERNS.

10. In which weight class do you compete? under __________kg.

11. Did you change your weight class in the last two years?
( ) yes. In which weight classes did you compete? ____________.
( ) no, I competed in the same weight class in the last two years

12. How much did you weigh in the last judo off-season *(especify the year)* ? _________ kg.

13. Have you ever lost weight in order to compete?
( ) Yes. (please continue aswering the rest of the questionnaire)
( ) No, I have never cut weight to compete (thank you for your help - do not answer the following questions).

14. What is the MOST WEIGHT that you have cut to compete in your career? _____________ kg.

15. How many times did you cut weight to compete last season *(especify the year)*?_____________ times.

16. How much weight do you **usually** cut before competitions? ______________ kg.

17. In how many days do you **usually** cut weight before competitions? ________________ days.

18. At what age did you begin to cut weight for competitions? _____________ years old.

19. How much weight do you usually regain in the week following a competition?___________ kg/week.

please continue on the next page

20. Using the scale below, please rate the amount of influence that each individual listed below has had on your weight loss practices. (i.e.: who encouraged and taugth you to lose weight) (check all items)

1	2	3	4	5
not influential	little influential	unsure	some influential	very influential

( ) another judoka/training colleague
( ) fellow judoka;
( ) physician/doctor;
( ) physical trainer;
( ) judo coach/ sensei;
( ) parents;
( ) dietitian;
( ) other. Explain ___________

21. The table below presents several methods to lose weight rapidly. Using the table below, HOW OFTEN did you use each one of the following methods to lose weight **before competitions**? (Check all items).

Gradual dieting (lose weight in 2 weeks or more)	always ( )	sometimes ( )	almost never ( )	never used ( )	I don't use anymore ( )
Skipping 1 or 2 meals	always ( )	sometimes ( )	almost never ( )	never used ( )	I don't use anymore ( )
Fasting (not eating all day)	always ( )	sometimes ( )	almost never ( )	never used ( )	I don't use anymore ( )
Restricting fluids ingestion	always ( )	sometimes ( )	almost never ( )	never used ( )	I don't use anymore ( )
Increased exercises (more than usual)	always ( )	sometimes ( )	almost never ( )	never used ( )	I don't use anymore ( )
Training intentionally in heated training rooms	always ( )	sometimes ( )	almost never ( )	never used ( )	I don't use anymore ( )
Saunas	always ( )	sometimes ( )	almost never ( )	never used ( )	I don't use anymore ( )
Training with rubber/plastic suits	always ( )	sometimes ( )	almost never ( )	never used ( )	I don't use anymore ( )
Use winter or plastic suits during the whole day and/or night (without exercising)	always ( )	sometimes ( )	almost never ( )	never used ( )	I don't use anymore ( )
Spitting	always ( )	sometimes ( )	almost never ( )	never used ( )	I don't use anymore ( )
Laxatives	always ( )	sometimes ( )	almost never ( )	never used ( )	I don't use anymore ( )
Diuretics	always ( )	sometimes ( )	almost never ( )	never used ( )	I don't use anymore ( )
Diet pills	always ( )	sometimes ( )	almost never ( )	never used ( )	I don't use anymore ( )
Vomiting	always ( )	sometimes ( )	almost never ( )	never used ( )	I don't use anymore ( )

FIGURE 1. NOTE. REPRINTED FROM "DEVELOPMENT, VALIDITY AND RELIABILITY OF A QUESTIONNAIRE DESIGNED TO EVALUATE RAPID WEIGHT LOSS PATTERNS IN JUDO PLAYERS," BY, ARTIOLI, G. G., SCAGLIUSI, F., KASHIWAGURA, D., FRANCHINI, E., GUALANO, B., & JUNIOR, A. L., 2010. . SCANDINAVIAN JOURNAL OF MEDICINE & SCIENCE IN SPORTS, 20. APPENDIX 2.

APPENDIX B: Summary of Research Presented in Section Concerning Prevalence of Rapid Weight Loss.

Sport	*Study*	*Number of participants*	*Results*
Judo	Artioli, Gulano et al. (2010)	n=822 607 males, 215 females	• 86% of surveyed athletes had lost weight to compete when heavyweights were included. That number rose to 89% when heavyweights were excluded. • Average weight lost: **2-5%**
	do Nascimento et al. (2020)	n=186 junior level athletes. • 47 novices (less than 2 years' experience competing) • 139 experienced (greater than 2 years' experience)	• Regardless of experience level, 77% of athletes surveyed reported some form or practice of RWL. • Average weight lost: **1 kg during the 7 days before the competition**.
Mixed Martial Arts (MMA)	Connor & Egan (2019)	n=30 15 professional, 15 amateurs	• 97% of athletes reported engaging in RWL before competition. • Average weight lost: **7.9%**
	Hillier et al. (2019)	n=314 287 males, 27 females	• 97.2% of males and 100% of females reported engaging in RWL. • Average weight lost week of competition between professionals: **5.9% of males and 4.2% of females** • Average weight lost week of competition between amateurs: **5.0% of males and 2.1% of females** • Average weight lost 24 hours before competition: **3.7% of pros and 2.5% of amateurs**
Taekwondo	da Silva Santos et al. (2016)	n=116 • 72 males (31 regional/state level, 41 national/international level) • 44 females (9 state/regional level, 35 national/international)	• 77.4% of regional/state level and 75.6% of national and international level male competitors reported engaging in RWL • 88.9% of regional/state level and 88.6% of national/international female competitors reported engaging in RWL • Average weight lost: **3%**

Kickboxing	Dugonjić et al. (2019)	n=61		• Approximately 30% of athletes reported losing between 6-8% of body mass • Most (81.2%) reported losing between 0-5% of body mass • 100% of respondents reported losing weight to compete
Multiple Disciplines *(judo, jiu-jitsu, taekwondo, and karate)*	Brito et al. (2012)	n=580		• Regardless of sport, 60% of surveyed athletes reported engaging in RWL through increased energy expenditure.

TABLE 1

APPENDIX C: Physiological Profiles of Wrestlers (Chaabene et al., 2017)

Physical Performance Characteristics	Tests	Results/score		
		Men	Women	Cadets
Aerobic capacity/endurance	VO_2 max (treadmill, cycle ergometer, shuttle run)	37 to 61 ml*kg^{-1}*min^{-1}	39 to 52 ml*kg^{-1}*min^{-1}	42 to 58 ml*kg^{-1}*min^{-1}
Anaerobic capacity/endurance	Wingate test (8 sec., 30 sec., 1 minute). Mean power (MP) and Peak power (PP)	Lower limb PP: 10 to 17 W*kg^{-1}	Lower limb PP: 7 to 9 W*kg^{-1}	Lower limb PP: 8 to 15 W*kg^{-1}
		Lower limb MP: 4 to 9 W*kg^{-1}	Lower limb MP: 4 to 7 W*kg^{-1}	Lower limb MP: 6 to 7 W*kg^{-1}
		Upper body PP: 7 to 11 W*kg^{-1}		Upper body PP: 8 to 11 W*kg^{-1}
		Upper body MP: 4 to 7 W*kg^{-1}		Upper body MP: 4 to 5 W*kg^{-1}
Maximal dynamic strength	One-repetition maximal (1RM) test (bench press, squat, power clean, snatch, deadlift)	1RM squat: 87 to 150 kg		
		1RM bench press: 74 to 130 kg		
		1RM power clean: 72 to 140 kg		
Isometric strength	Back, leg, and handgrip dynamometer test	Handgrip Strength: 38 to 63 kgf	Handgrip Strength: 27 to 35 kfg	Handgrip Strength: 31 to 53 kfg.
		Lower Back Strength: 114 to 213 kgf.	Lower Back Strength: 85 to 116 kgf.	Lower Back Strength: 122 to 185 kgf
		Leg Strength: 168 to 272 kgf		Leg Strength: 165 to 228 kgf.

Muscle power/anaerobic power	Vertical and Horizontal jump tests (Countermovement jump, vertical jump, squat jump, or standing long jump) CMJ: Countermovement jump SLJ: Standing long jump	Mean CMJ: 47 to 61 cm		
		Mean CMJ (junior males): 33 to 59 cm		
		Mean SLJ: 196 to 250 cm		
Muscular endurance	Max. number of push-ups, sit-ups, pull-ups, or dips performed per minute	Push-ups: 54 to 70/min.		
		Sit-ups: 52 to 77/min.		
		Pull-ups: 15 to 50/min.		

Table 2

Note. Data on lower back isometric strength in women consisted of only one study. Data retrieved from, "Physical and physiological attributes of wrestlers: An update" by, Chaabène, H., Negra, Y., Bouguezzi, R., Mkaouer, B., Franchini, E., Julio, U., & Hachana, Y., 2017. *Journal of Sports Sciences 31*. pp. 1411-1442.

APPENDIX D: Physiological Profile of Brazilian Jiu-Jitsu Athletes (Andreato et al., 2017)

Physical Performance Characteristics	Tests	Results/score
Aerobic capacity/endurance	VO_2 Max Test (i.e. treadmill, 1,600 and 2,400 m test, Queen's College Step Test)	42 to 52 ml*kg^{-1}*min^{-1}
Anaerobic capacity/endurance	Wingate test (8 second, 30 second, 1 minute) Mean Power (MP) and Peak Power (PP).	
Maximal Dynamic Strength	Relative (kg/body mass) One-repetition maximal (1RM) score (i.e. bench press, squat, deadlift)	1RM squat: 1.2 to 1.4 kg/body mass 1RM bench press: 1.3 to 1.5 kg/body mass 1RM Deadlift: 1.7 kg/body mass
Isometric Strength	Handgrip dynamometer tests	Handgrip Strength: 48 to 57 kg
Muscle Power	Vertical and Horizontal Jump tests (Countermovement Jump ((CMJ)), vertical jump, squat jump, or Standing Long Jump ((SLJ)))	CMJ ranges: 30 to 45 cm Vertical Jump mean ranges: 39.9 to 48.3 cm. SLJ mean ranges: 225 to 237 cm
Muscular Endurance	Grip endurance test with gi, repetition test with gi, maximum number of push-ups, and sit-ups	Max number of push-ups per minute: 36 to 41 repetitions Max number of sit-ups per minute: 40 to 68 repetitions Mean grip endurance test with kimono (for time): 54 to 62 sec. Mean grip endurance test with kimono (for repetitions): 15 to 18 reps

Table 3.

Note. Data retrieved from, "Physical and physiological profiles of brazilian jiu-jitsu athletes: A systematic review" by, Andreato, L. V., Lara, F. J. D., Andrade, A., & Branco, B. H. M., 2017. *Sports Medicine - Open, 3*. pp. 9.

APPENDIX E: Physiological Profiles of Taekwondo Athletes (Bridge et al., 2014)

Physical Performance Characteristics	Tests	Results/score	
		Men	Women
Aerobic capacity/endurance	VO_2 max (treadmill, cycle ergometer, or shuttle run)	44 to 63 $ml*kg^{-1}*min^{-1}$	40 to 51 $ml*kg^{-1}*min^{-1}$
Anaerobic capacity/endurance	Wingate test (30 sec.)	Lower body relative Peak Power (PP): 8.4 to 14.7 W/kg	Lower body relative Peak Power (PP): 6.6 to 10.2 W/kg
Maximal dynamic strength	Relative (kg/BM) mean 1RM score (bench press using machines or free weights, leg press, and back squat). 2 studies	Experienced recreational level machine bench press 1RM: 1.23 kg/body mass Novice recreational level machine bench press 1RM: 1.06 kg/body mass Experienced recreational level leg press 1RM: 3.2 kg/body mass Novice recreational level leg press 1RM: 2.4 kg/body mass	Experienced recreational level machine bench press 1RM: 0.62 kg/body mass Novice recreational level machine bench press 1RM: 0.57 kg/body mass Experienced recreational level leg press 1RM: 2.6 kg/body mass Novice recreational level leg press 1RM: 2.3 kg/body mass Croatian international medalist bench press 1RM: 0.9 kg/body mass Croatian international non-medalist bench press 1RM: 0.8 kg/body mass Croatian international medalist back squat 1RM: 1.4 kg/body mass

			Croatian international non-medalist back squat 1RM: 1.2 kg/body mass
Isometric strength	None reported or performed		
Muscle power/anaerobic power	Vertical and horizontal jump (countermovement jump, vertical jump, squat jump, or standing long jump) CMJ: Countermovement jump SLJ: Standing long jump	Squat or static jump ranges: 35.8 to 45.4 cm	Squat or static jump ranges: 23.7 to 29.8 cm
Muscular endurance	Max. number of sit-ups per minute	48 to 52/min.	52 to 59/min.

Table 4.

Data retrieved from, "Physical and physiological profiles of taekwondo athletes" by, Bridge, C. A., Ferreira da Silva Santos, Jonatas, Chaabène, H., Pieter, W., & Franchini, E., 2014. *Sports Medicine 44*. pp. 713-733

APPENDIX F: Physiological Profiles of Boxers (Chaabene et al., 2015)

Physical performance characteristics	Tests	Results/score
Aerobic capacity/endurance (VO_2 max)	Continuous graded exercise test (cycle ergometer or treadmill)	Males: 49 and 65 ml/kg/min Females: 44 and 52 ml/kg/min
Anaerobic capacity/endurance (peak power, mean power)	30 second Wingate test	Mean power senior males: mean ± SD 6.5 ± 0.5 W/kg Mean power junior males: mean ± SD 4.9 ± 0.7 W/kg
Maximal dynamic strength	Punching force (piezoelectric force transducer)	
Muscular power/anaerobic power	Shot put test (upper limb power) Vertical jump/horizontal jump test (lower limb power)	
Isometric Strength	Hand-grip isometric strength test	

TABLE 5.

NOTE. DATA RETRIEVED FROM, "AMATEUR BOXING: PHYSICAL AND PHYSIOLOGICAL ATTRIBUTES: BY, CHAABÈNE, H., TABBEN, M., MKAOUER, B., FRANCHINI, E., NEGRA, Y., HAMMAMI, M., AMARA, S., CHAABÈNE, R. B., & HACHANA., 2015. *SPORTS MEDICINE 45*. PP. 337–352.

APPENDIX G: Experimental Design of Study

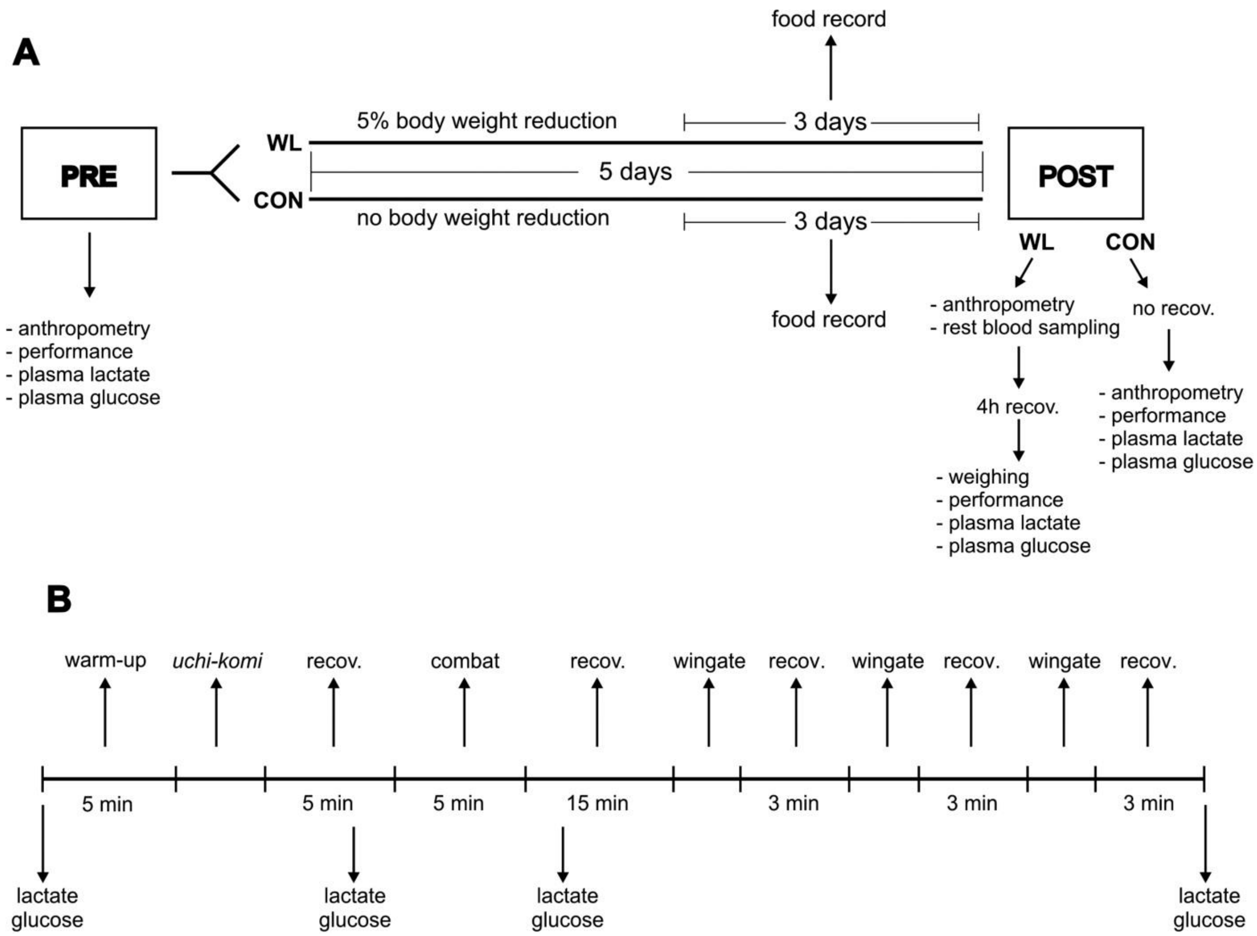

FIGURE 2

FIGURE A REPRESENTS THE WEIGHT LOSS PROTOCOL FOR BOTH THE CONTROL GROUP (CON) AND THE WEIGHT LOSS GROUP (WL). FIGURE B REPRESENTS THE BREAKDOWN OF THE PERFORMANCE TESTING DONE ON THE PARTICIPANTS. NOTE. REPRINTED FROM "RAPID WEIGHT LOSS FOLLOWED BY RECOVERY TIME DOES NOT AFFECT JUDO-RELATED PERFORMANCE" BY, ARTIOLI, G. G., IGLESIAS, R. T., FRANCHINI, E., GUALANO, B., KASHIWAGURA, D. B., SOLIS, M. Y., . . . LANCHA,ANTONIO H.,,JR., 2010. *JOURNAL OF SPORTS SCIENCES 28*. P. 23.

APPENDIX H: Experimental Design of Study

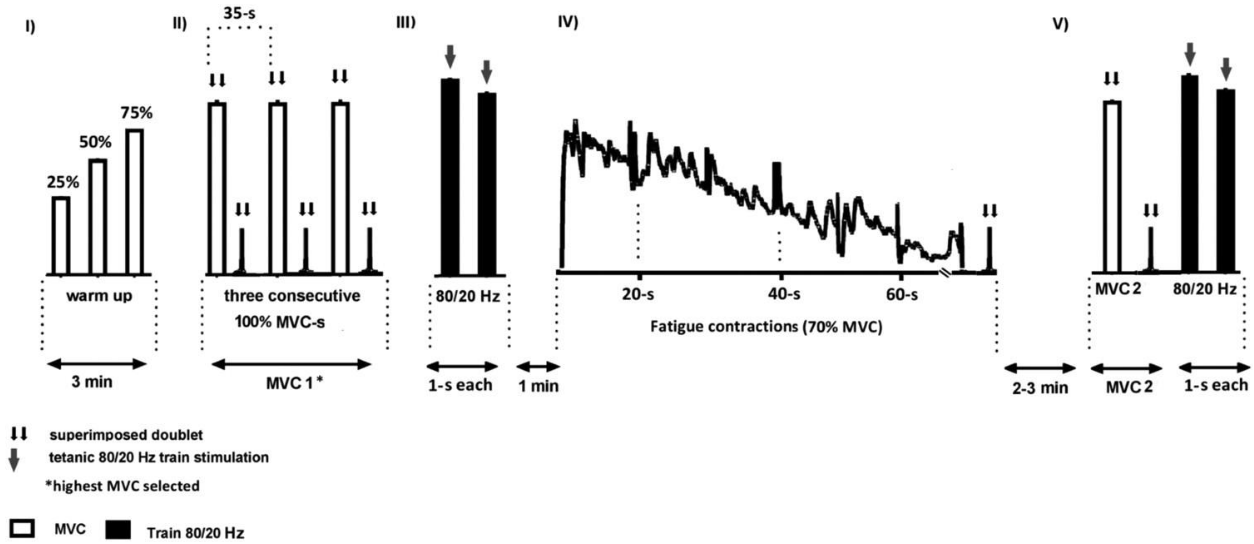

FIGURE 3

NOTE. REPRINTED FROM "NEUROMUSCULAR PERFORMANCE AFTER RAPID WEIGHT LOSS IN OLYMPIC-STYLE BOXERS", BY ZUBAC, D., ŠIMUNIČ, B., BUOITE STELLA, A., & MORRISON, S. A., 2019. EUROPEAN JOURNAL OF SPORT SCIENCE. P. 3.

APPENDIX I: Summary Table

Physical Performance Measure	Study	Baseline Measurement	Change after weight loss (2-6%)
Isometric Strength (Handgrip)	Alves et al., 2018	51.7 ± 5.6c kg	47.8 ± 6.0c kg (At weigh in); 49.3 ± 5.4c kg (24 hours later)
	Barley, Iredale et al., 2018	53 ± 8 kg	51 ± 8 kg (3 hours later)
	Isaaco et al., 2019	Right hand (Match 1 WL group) 53 ± 6 kg	Right hand (Match 5 WL Group) 49 ± 7 kg
		Left hand (Match 1 WL Group) 51 ± 7 kg	Left hand (Match 5 WL Group) 48 ± 8 kg
	Kraemer et al. 2001	29 kg (morning measurement) 27.5 kg (evening measurement)	Match 5 (pre- and post-match measurement) 20 kg
Isokinetic Strength	Timpmann et al., 2008 (knee extension)	240 N*m (1.57 rad·s^{-1}) 120 N*m (3.14 rad·s^{-1})	220 N*m (1.57 rad·s^{-1}) 100 N*m (3.14 rad·s^{-1})
Upper Body Power	Barley, Iredale et al., 2018 (Medicine ball chest push)	474 ± 52 cm	449 ± 44 cm (24 hours post dehydration)
	Kurylas et al., 2019 (30 second Wingate test-Upper limbs)	**Peak Power** 4 weeks out: 976 W 2 weeks out: 982.38 W	**Peak Power** 1 day out: 672.43 W Fight day: 923.24 W
		Mean Power 4 weeks out: 464.70 W 2 weeks out: 467.70	**Mean Power** 1 day out: 397.00 Fight day: 460.70
Muscular Endurance/Time to Fatigue	Barley, Chapman, Blazevich, & Abbiss, 2018 (Total number of contractions completed during fatiguing protocol. Knee extensions)	23 ± 8 repetitions	17 ± 7 repetitions
	Zubac et al., 2019 (Time to exhaustion during fatiguing protocol at 70% of 1RM for max reps knee extensions)	85.9 ± 34.8 sec.	68.8 ± 20.2 sec.
Neuromuscular Function	Zubac et al., 2019 (Maximal Voluntary Contraction knee extensors)	257 ± 43 N	225 ± 37 N
Sport Specific Tasks	Koral & Dosseville, 2009 (Repetitions of Judo Movement over 30 seconds. Combination of gradual and rapid weight loss used)	**4 weeks before competition** 48.4+5.4 repetitions	**1 day before competition** 42.6+5.1 repetitions
	Hall et al., 2001 (Circuit training consisting of burpees and press-ups done continuously for 4 sets, 2 minutes each. Total number of reps done was measure of performance.)	**Training weight (Walk around weight)** Predicted reps: 285.5 Performed reps: 290.00	**Championship (competition) weight (Weight cut)** Predicted reps: 300.33 Performed reps: 289.27

TABLE 6. NOTE. DATA RETRIEVED FROM STUDIES LISTED IN TABLE.

PERMISSIONS

Request for permission to use table from research

SC

Sean Cavey
Mon 9/14/2020 12:53 PM

Like

To:

- Guilherme Giannini Artioli <artioli@usp.br>

Thank you so much for this permission sir. I really appreciate it.

Take Care and again Thank You,

Sean Cavey

Reply
Forward

GA

Guilherme Giannini Artioli <artioli@usp.br>
Mon 9/14/2020 11:06 AM

More actions

To:

- Sean Cavey

Dear Sean,

I am happy to 107uthorize any use of the published material you mentioned.

Best of luck to you in your Honor's project.

Kind regards,

Guilherme
Prof Guilherme G Artioli, PhD.
Applied Physiology & Nutrition Research Group, University of Sao Paulo.
Av. Prof. Mello Moraes, 65. Butanta, Sao Paulo, SP. Brazil.
Post code: 05508-030
Phone: +55 11 3091-8783
http://lattes.cnpq.br/7797827593708315
ResearcherID: K-5925-2013
orcid.org/0000-0001-8463-2213
www.cienciainforma.com.br

I might sometimes send emails outside normal working hours. Please do not feel you need to respond outside your own working hours.

Eventualmente, eu posso enviar emails I do horário de trabalho normal. Por favor, não se sinta obrigado a respondê-los I de seu horário de trabalho.

SC

Sean Cavey
Sat 9/12/2020 10:09 PM

To:

- artioli@usp.br

Hello Professor Artioli,

My name is Sean Cavey and I am currently an undergraduate student at the University of Central Florida majoring in exercise science/kinesiology. I am currently writing a narrative literature review for the Honor's College on the physical performance effects of rapid weight loss in combat sports athletes. I examined research from the past 20 years to complete my narrative review and cited the article you published in 2010 titled, "Rapid weight loss followed by recovery time does not affect judo-related performance." In it, you and your colleagues created 2 diagrams which gave a visual representation of the methods used to obtain the data as well as the timing of the testing.

I was emailing you this evening asking you for your permission to use both diagrams (A & B) to better illustrate and represent the methods you and your colleagues used to collect the data in the study.

Thank You for your time and consideration for this request. I appreciate it.

Sean Cavey

Request of Permission

SC

Sean Cavey
Mon 11/9/2020 11:14 AM

To:

- Guilherme Giannini Artioli <artioli@usp.br>

Thank you very much, professor. I appreciate the permission again to be able to utilize the research. I am sorry for the late reply also.

Thank you again,

Sean Cavey

Reply
Forward

GA

Guilherme Giannini Artioli <artioli@usp.br>
Thu 11/5/2020 1:00 PM

Like

To:

- Sean Cavey

Dear Sean,

I am happy to give you permission for any use you need to make of the questionnaire.

I wish you best luck with your research.

All the best,

Guilherme

Prof Guilherme G Artioli, PhD.
Applied Physiology & Nutrition Research Group, University of Sao Paulo.
Av. Prof. Mello Moraes, 65. Butanta, Sao Paulo, SP. Brazil.
Post code: 05508-030
Phone: +55 11 3091-8783
http://lattes.cnpq.br/7797827593708315
ResearcherID: K-5925-2013
orcid.org/0000-0001-8463-2213
www.cienciainforma.com.br

I might sometimes send emails outside normal working hours. Please do not feel you need to respond outside your own working hours.

Eventualmente, eu posso enviar emails I do horário de trabalho normal. Por favor, não se sinta obrigado a respondê-los I de seu horário de trabalho.

SC

Sean Cavey
Thu 11/5/2020 12:31 PM

To:

- Guilherme Giannini Artioli <artioli@usp.br>

Hello Professor Artioli,

My name is Sean Cavey. I was sending this email as a request for permission to use Appendix 2 from the article you and your colleagues wrote titled, "Development, validity and reliability of a questionnaire designed to evaluate rapid weight loss patterns in judo players." The Appendix which I am specifically referring to is the English language version of the Rapid Weight Loss Questionnaire. I would like to cite the Questionnaire in my Appendix section as a visual representation to accompany the section in which I refer to the Questionnaire in the review to represent better your and your colleague's research.

I would appreciate this permission from you greatly sir. We have spoken in the past not too long ago about permission that you granted me in order to use a figure of a testing protocol in another study you conducted as well.

I appreciate your time and consideration for this permission.

Thank You kindly,

Sean Cavey

P.S. Just a little background information on me and the nature of my research. It is a narrative review of the physical performance effects of rapid weight loss in combat sports for the Honors Undergraduate Thesis Program at UCF majoring in exercise science. I forgot to include that in the intro of this email. Thank you again.

Request for Permission to use diagram from Research

SC

Sean Cavey
Wed 10/7/2020 11:30 AM

To:

- Damir Zubac <damzub@kifst.hr>

Yes sir of course. Thank you very much for the permission.

Reply
Forward

DZ

Damir Zubac <damzub@kifst.hr>
Wed 10/7/2020 10:59 AM

To:

- Sean Cavey

Dear Sean

Sorry for a very delayed response. Your email ended up in my spam. Yes, you can use any figure you wish as long as you cite properly.

Best, Damir

Dana 2020-09-13 04:28, Sean Cavey je napisao(la):
> Hello Professor Zubac,
>
> My name is Sean Cavey and I am currently an undergraduate student at
> the University of Central Florida majoring in exercise
> science/kinesiology. I am writing a narrative literature review for
> the Honor's Undergraduate Program on the physical performance of rapid
> weight loss in combat sports athletes. I reviewed the research over
> the past 20 years examining athletes from multiple combat sports
> following a period of rapid weight loss and what the process of weight
> cutting did to physical performance measures such as anaerobic power,
> VO2 max levels, etc.
>
> In my curation of the research, I cited research done by you and your
> colleagues in 2019 which was titled, "Neuromuscular performance after
> rapid weight loss in Olympic-style boxers." In the research article,
> labeled Figure 1, is a chart illustrating the methods used to obtain
> the data collected in the study.
>
> I am writing to you this evening to ask you for your permission to
> cite/use the figure created by you and your colleagues to also
> illustrate to the potential readers of my thesis the methods used in
> the study conducted in 2019. I feel it would be great for
> clarification purposes.
>
> I appreciate your time in reading this email and consideration for
> potentially approving my request for permission Professor. I
> appreciate it.
>
> Sean Cavey

--
Damir Zubac, PhD, Research fellow
University of Split, Faculty of Kinesiology, Split, Croatia
Science and Research Center Koper, Institute for Kinesiology Research,
Koper, Slovenia
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SC

Sean Cavey
Sat 9/12/2020 10:28 PM

To:

- damir.zubac@kifst.hr

Hello Professor Zubac,

My name is Sean Cavey and I am currently an undergraduate student at the University of Central Florida majoring in exercise science/kinesiology. I am writing a narrative literature review for the Honor's Undergraduate Program on the physical performance of rapid weight loss in combat sports athletes. I reviewed the research over the past 20 years examining athletes from multiple combat sports following a period of rapid weight loss and what the process of weight cutting did to physical performance measures such as anaerobic power, VO2 max levels, etc.

In my curation of the research, I cited research done by you and your colleagues in 2019 which was titled, "Neuromuscular performance after rapid weight loss in Olympic-style boxers." In the research article, labeled Figure 1, is a chart illustrating the methods used to obtain the data collected in the study.

I am writing to you this evening to ask you for your permission to cite/use the figure created by you and your colleagues to also illustrate to the potential readers of my thesis the methods used in the study conducted in 2019. I feel it would be great for clarification purposes.

I appreciate your time in reading this email and consideration for potentially approving my request for permission Professor. I appreciate it.

Sean Cavey

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