EFFECT OF NUTRITION INTAKE AND CHANGES IN BODY COMPOSITION ON INCIDENCE OF INJURY IN COLLEGIATE WRESTLERS

A Thesis
by
TYLER D. ROOF

Submitted to the School of Graduate Studies
at Appalachian State University
in partial fulfillment of the requirements for the degree of
MASTER OF SCIENCE

May 2021
Department of Nutrition and Health Care Management

EFFECT OF NUTRITION INTAKE AND CHANGES IN BODY COMPOSITION ON INCIDENCE OF INJURY IN COLLEGIATE WRESTLERS

A Thesis
by
TYLER D. ROOF
MAY 2021

APPROVED BY:

Laurel Wentz, Ph.D.
Chairperson, Thesis Committee

Danielle Nunnery, Ph.D.
Member, Thesis Committee

Marco Meucci, Ph.D.
Member, Thesis Committee

Margaret Barth, Ph.D.
Chairperson, Department of Nutrition and Health Care Management

Michael McKenzie, Ph.D.
Dean, Cratis D. Williams School of Graduate Studies

Abstract

EFFECT OF NUTRITION INTAKE AND CHANGES IN BODY COMPOSITION ON INCIDENCE OF INJURY IN COLLEGIATE WRESTLERS

Tyler D. Roof
B.S., University of Georgia
M.S., Appalachian State University

Chairperson: Laurel Wentz, Ph.D.

Background: Weight management practices and manipulations in body composition may impair health and sports performance, but their strategic use can improve competitive success in weight class sports. Wrestling is a sport where athletes employ methods of acute energy restriction to compete in a weight class. Ideally, wrestlers should consume enough calories to provide for both baseline energy requirements of normal living and growth, as well as the requirements of repairing muscle mass. However, wrestlers will use forms of energy restriction to make weight. Changes in body composition and poor weight management practices may increase the likelihood of injury occurrence. **Purpose:** To investigate acute and longitudinal nutrition practices, changes in body composition, and incidence of injuries in division one male collegiate wrestlers across the competitive season. **Methods:** Data were collected from twenty-eight student-athletes of the Appalachian State University Wrestling team. Nutrition practice was assessed via questionnaires and, a three-day food record. Body mass was measured using a digital scale. Dual-energy X-ray absorptiometry (DXA) whole body scan was used to assess fat-free mass in kg (FFM) and body fat (BF) percentage. In-season competition and practice injury data were collected from the team's certified athletic trainer (ATC). Student's t-tests were used to compare differences in continuous data, and Chi-square tests were used to compare differences in categorical variables. **Results:** Wrestlers significantly changed their BM from pre- to mid-season (80.2 ± 14.9 kg vs 77.9 ± 14.9 kg, $p < 0.001$). Wrestlers decreased FFM (63.5 ± 10.7 kg vs 62.0 ± 10.6 kg, $p < 0.001$) and decreased BF (16.5 ± 2.6% vs 15.9 ± 2.8%, $p = 0.020$) from pre- to mid-season DXA scans. Of the twenty-eight participants, nine wrestlers experienced at least one injury throughout the season. Changes in BM, FFM, and BF were not significantly different between those who experienced an injury and those who did not. There were no significant differences in methods of weight loss or mass lost immediately prior to competition between injured and non-injured wrestlers. The most popular methods of weight loss for both acute and longitudinal weight loss practices, active sweating and energy restriction, were congruent with the current literature. The most popular type of injury was congruent with other studies, as 53% of the total injuries sustained were classified as sprains by the ATC. **Conclusion:** We found significant changes in overall BM, FFM, and BF percentage from pre- to mid-season, but no differences by injury. Restrictive dietary intake and weight-loss methods were not linked to incidence of injury. Our data are limited by early season termination due to COVID-19 and small number of collected food records. Future research should focus on dietary interventions to manipulate body composition to determine a relationship between nutrition and injury risk.

Acknowledgments

I would like to recognize the Appalachian State University Wrestling Team for their time; and the Appalachian State Athletics Staff for their efforts in making this data acquisition possible. I would like to extend my sincerest gratitude to my mentor, Dr. Laurel Wentz, for her guidance and support during my graduate studies at Appalachian State University. To all other staff of the Nutrition and Health Care Management graduate program, I express my thanks for your involvement in my learning. To my fellow graduate students, I thank you for your friendships over the past two years and look forward to the opportunities that may bring us together in the future. And lastly, I especially appreciate my mother and sister, who have always been my biggest encouragers and greatest supporters of making my dream of education become a reality.

Dedication

To the resilient women; past, present and future, whose paths intertwine with mine. To my mother specifically, I am grateful for your unconditional love, and for your ability to withstand the hardest of life's trials. You exemplify determination, tenacity, and integrity in all that you do. I aspire to be more like you.

Table of Contents

Chapter 1: Introduction

Problem

Sports participation among adolescents in American has a myriad of benefits. Research shows that adolescents participating in sports show a positive increase not only in physiological outcomes, but in psychological outcomes as well (Janssen, 2007). Other secondary health outcomes specific to team sports include personal development, such as increased self-esteem and confidence, as well as improved verbal communication skills (Malm et al., 2019). However, participation in sport may have negative health implications, specifically the biggest barrier for sports participation being risk for injury (Emery, 2009).

Although collegiate folkstyle wrestling has fewer participants compared to larger revenue team sports, the nature of the sport increases the risk of injury (Kroshus, et al., 2018). Wrestling is a contact sport where decisions must be made quickly. Impact with the mat, floor, or other players is inevitable. One study by Agel et al. (2007) found that 55% of match injuries resulted from player contact, whereas other contact (primarily mat) accounted for 22.9% of injuries, while the majority of practice injuries (63.6%) involved player contact. Repeated exposure to incidences where injuries frequently occur designates the sport as high risk. In collegiate wrestling, the most frequently injured body parts for both practices and competitions were the knee (practices = 16.7%, competitions = 30.4%) and the head or face (practices = 12.1%, competitions = 14.6%) (Kroshus, et al., 2018). The risk of fracture (7%), dislocation/subluxation (6%), cruciate/collateral ligament tears and cartilage injury (17%), and sprain (38%) are high risk types of injuries that are specific to the sport (Thomas & Zamanpour, 2018). Both intrinsic factors such as leg dominance and anatomical size, and extrinsic factors such as skill, equipment and mat surface, affect risk of injury among wrestlers (Pfeifer et al., 2018). While most intrinsic factors cannot be easily manipulated or controlled, proper weight cutting and nutrition practices, although extrinsic, can have influence on intrinsic body composition (Wild, Rahbarnia, Kellner, Sobotka, & Eberlein, 2010).

Managing weight for a student-athlete participating in a weight dependent sport is critical for optimizing performance. Although manipulations in body mass may impair health and sports performance, their strategic use can improve competitive success. Ideally, athletes should consume enough calories to provide for both baseline energy requirements of normal living and growth, as well as the requirements of daily activity, building and repairing muscle mass, and nutrient replacement (Rodriguez, DiMarco, Langley, 2009). Wrestling, however, is a sport where athletes will use methods of acute energy restriction in order to compete in their desired competition weight class. A number of weight cutting practices may be used, including: energy restriction, fiber restriction, salt restriction, glycogen depletion, passive and active sweating, or other methods such as fat burners and laxatives (Reale, Slater, & Burke, 2017). These methods may be used singularly or in combination with one another.

It is generally accepted that extreme weight loss due to low energy availability is a mismatch between an athlete's energy intake in the diet and the energy expended in exercise, leaving inadequate energy to support the functions required by the body to maintain optimal health and performance (Mountjoy, et al., 2018). While we acknowledge that weight restriction is in the nature of the sport, consequences of extreme weight cutting measures like relative energy deficiency in sport (RED-S) are valid and must be considered when dealing with such a susceptible population of athletes. With athletes participating in weight dependent sports like wrestling, despite the improvement of the knowledge base of RED-S in male athletes, there still remains a gap in our understanding of the effects of RED-S in specific sports with differing energy demands and performance criteria (Mountjoy, et al., 2018).

With weight cutting and body composition changes being a common practice in the sport of wrestling, it is essential to monitor both nutritional status and physical health related to injury risk. To our knowledge, no study has yet to explore the relationship of nutritional weight cutting practices employed by collegiate wrestlers, and the effects of body composition on incidence for injury.

Scientific Rationale

Wrestling athletes undertake chronic and rapid weight loss practices to qualify for weight class divisions lower than their training weight. The primary purpose of these athletes' weight loss practices is to gain the best possible advantage against their opponent via stronger and larger body composition, while maintaining maximal health and physical fitness. Steen & Brownell, 1990, concluded that clear patterns emerged showing frequent, rapid, and large weight loss and regain cycles with 41% of collegiate wrestlers reporting weight fluctuations of 5.0 to 9.1 kg each week of the season. With this magnitude of rapid weight loss, including loss of fat-free mass (FFM), protective measures against injury incidence are hypothesized to be reduced with nutritionally sound practices to alter body mass (Steen & Brownell, 1990).

In older adults, there is an increasing body of evidence linking the loss of muscle strength, also referred to as sarcopenia, that occurs with advancing age to an increased risk for falls (Schneider & Trence, 2019). Similarly, in clinical dietetic practice, evidence shows quality nutrition is vital for wound healing to help body supply the necessary building blocks and cellular response to promote healing (Dryden, Shoemaker, & Kim, 2013). While there is no current study, to our knowledge, that links sports injury to dietary intake, there is literature available on nutritional practices and body composition changes. Because a body composed of a greater proportion of FFM may possess a greater strength capacity, body composition may be a crucial factor in our understanding of injury risk (Montgomery, Shultz, Schmitz, Wideman, & Henson, 2012).

Body composition can be influenced by many factors, most commonly energy restriction. Energy restriction in the form of calorie restriction is a common method for both acute and longitudinal weight loss, however total energy intake and metabolic weight loss is not nutritionally equivalent. Weight loss by energy restriction can significantly reduce anaerobic performance of wrestlers (Rankin, Ocel, & Craft, 1996). To counteract the low energy availability, metabolic adaptation occurs to promote energy conservation, making the athlete more susceptible to higher injury rates pertaining to torn muscles and ligaments, which are some of most common types of injuries within the wrestling population (Thomas & Zamanpour, 2018).

Protein consumption plays a vital role in weight class sports. Meta-analytic data support mean intake of ~1.6 g/kg/day to maximize FFM gains with resistance training (Morton, et al., 2017). A recent study found that over a 4-week period, a 40% caloric deficit with 2.4 g/kg/day of protein resulted in more lean body mass preservation and more fat mass loss compared to a group consuming 1.2 g/kg/day (Longland et al., 2016). This study exemplifies that the restriction of protein consumption may result in loss of FFM and is not ideal for wrestling athletes striving to reduce injury occurrence while also maintaining strength during competition.

Studies have reported inconclusive findings on the effects of energy and protein restriction on athletic performance, but carbohydrate restriction has been shown to be detrimental to sports performance due to fatigue (Finn, Dolgener, Williams, 2004). Muscle glycogen and blood glucose are important fuels for increased ATP production during exercise and are necessary in caloric deficits to preserve muscle mass in addition to glycogen stores needed for optimum performance (Hargreaves, 2015). One study, found that collegiate wrestlers consuming a high carbohydrate refeeding diet recovered their performance post weigh-in, while those on a moderate carbohydrate diet did not recover their performance as effectively in comparison (Rankin et al., 1996). Although the evidence is conflicting, most studies indicate that weight loss decreases both aerobic and anaerobic performance, the latter of which is mainly related to this effect of glycogen depletion (Franchini, Brito, & Artioli, 2012). However, it is important to note that there is a recovery period after official weigh-ins prior to competition (1-2 hours), in which glycogen stores may be replenished through nutrition. By consuming simple carbohydrates, the athlete may reduce the symptoms of fatigue associated with low blood glucose from previous acute weight loss strategies.

One of the most common weight cutting practices employed by wrestlers is water restriction, which in combination with other acute weight cutting methods of active and passive sweating, can lead to severe dehydration (Zubac, et al., 2019). Water is the most essential nutrient of the body, undergoing continuous recycling, functioning as a solvent, and regulating cell volume, all while playing a critical role in thermoregulation and overall function of the body. Dehydration can lead to physical fatigue, confusion, decreased cognitive function and performance (Nédélec, et al., 2012). The lack of concentration and focus can affect the ability of the athlete to deal with distractions during high-level competitions. Likewise, confusion can negatively affect the capacity of quick decision making during the match and result in lack of control by the athlete, possibly resulting in loss of the match or incidence of injury.

Some negative physiologic effects may occur due to long term low total energy availability, ranging from metabolic changes and abnormal hormone profiles to impaired bone health; but the decrease in use of lean muscle mass can lead to detrimental effects on athletic performance and insight incidence for injury (Rodriguez, DiMarco, Langley, 2009). Weight loss strategies that preserve lean body mass (LBM) are critical because the loss of LBM causes lowered resting energy expenditure, decline in neuromuscular function, fatigue, and an overall increased risk for injury (Willoughby, Hewlings, & Kalman, 2018). Furthermore, the metabolic decline that occurs after LBM loss results in a regain of fat mass, an unfavorable change in body composition (Lowe, Doshi, Katterman, & Feig, 2013).

Assessment of Body Composition

The body composition of athletes is assessed via many different methods, all of which have limitations. Dual x-ray absorptiometry (DXA), which provides whole body and regional estimates of fat-free mass, fat mass, and bone mineral content, is the current gold standard for body composition measurement (Sundgot-Borgen, et al., 2013). DXA technology also has the ability to measure four regions of the body separately (head, trunk, arms, legs) and can be used to determine bilateral differences in body composition. DXA is practical, requires no active subject involvement, and imposes minimal risk with low emittance of x-ray (Marra, et al., 2019).

The effect of effect of both acute and longitudinal weight loss on the performance of combat sport athletes, including wrestlers, has been of interest to researchers for many years with conflicting and inconsistent results. It is understood that wrestlers will compete at a body weight lower than their training weight with the desire to retain as much fat-free mass (FFM) as possible. The question that remains to be answered is at what point is this no longer advantageous for the athlete's performance and health. Studies observed a significant decrease in both total and lean body mass in college wrestlers from pre-season to post-season (Song & Cipriano, 1984). It was found that adolescent wrestler's FFM, power, and strength all declined from pre-season to post-season (Roemmich & Sinning, 1996). Utter et al. reported that college wrestlers who lose a significant amount of FFM during the competitive season were successful at maintaining both isometric muscular strength and anaerobic power, despite numerous bouts of traditional weight-cycling behavior.

To date, few studies have looked at energy balance in relation to body competition changes across the season of various team sports. No changes were found in relation to energy balance and changes in body composition over the time span of the various team sports seasons (not including wrestling) although a negative energy balance of negative 17.4 ± 72.2 kcals per day was observed (Silva, et al., 2017). Furthermore, Bartlett et al. (2019), found that athletes in a negative 229 ± 222 kcal per day energy deficit during preseason (67 ± 12 days) can increase fat free soft mass tissue (1.6 ± 1.9kg) and decrease fat mass (1.4 ± 1.3kg) suggesting that body composition may be optimized during select seasonal time frames.

More research is needed to clarify the relationship of energy balance and body composition profile according to sports-specific nutritional requirements like wrestling. No study, to our knowledge, has yet to employ the use of DXA technology as a method of tracking body composition changes across multiple points of the collegiate wrestling season while also assessing nutritional practices of energy intake and expenditure. Energy balance and the effect of changes in body composition is warranted to be studied further to explore the incidence and risk of injury. The possibility of limiting injury through proper nutritional practices would provide a protective edge to optimizing athletic performance and minimizing negative health implications.

Significance

To our knowledge, no previous work has examined weight class, athlete's nutrition practices, and behaviors and their effects on injury. Weight cutting fatigue mechanisms induced by inadequate energy, protein, and glycogen storages can be counteracted through proper nutrition and hydration strategies and warrants further study (Nédélec, et al., 2012). It is understood that failure to meet adequate energy availability may lead to detrimental consequences in athletic performance and perhaps increase the likelihood of injury, but it has yet to be understood the limit at which weight cutting practices are safe to be employed by weight-class athletes (Rodriguez, DiMarco, Langley, 2009).

Continued study of injury prevention related to nutrition practices in wrestlers across levels of competition is warranted, as consequences of injury can be detrimental to an athlete's physical and psychological health (Kroshus, et al., 2018). With injury, an athlete loses time from sport and is accompanied by uncomfortable pain or rehabilitation, resulting in overall dissatisfaction and lower quality of life for the athlete.

It is generally accepted that one of the best predictors of future injury is past injury (Quarrie, 2001). In a study conducted on male soccer athletes, the majority of all time loss due to injuries stems from injuries with an individual absence of up to four weeks (Ekstrand, et al., 2019). Minimizing injury will minimize risk associated with the effects enacted by time spent away from the sport. Nutritional practices related to body composition changes and injury risk are a crucial area of research that should be further explored in order to minimize these negative health implications.

Goals

This study aims to investigate acute and longitudinal weight loss nutrition practices, changes in body composition, and incidence of injuries in division one male collegiate wrestlers across the competitive season.

Aim 1: To explore acute and longitudinal nutrition practices used to meet competition weight class. It is hypothesized that the majority (> 80%) of collegiate wrestlers studied use energy restriction in short term (3-5 days preceding competition) and long term (across season) by limiting total food intake, especially carbohydrates and fat.

Aim 2: To investigate effects of nutritional practices on body composition and injury occurrence. It is hypothesized that energy restriction across the season is associated with loss of both fat-free mass and body fat mass. It is hypothesized that collegiate wrestlers who experienced an injury, practice greater energy restriction per kg FFM and lost more body mass in the week preceding competition than those who do not have an injury.

Chapter 2: Methods and Procedures

Methods

Participants

Student-Athletes from Appalachian State University's varsity wrestling roster were invited to participate in the study approved by and in accordance with Appalachian State University's institutional review board. Twenty-eight participants enrolled, with athletes in all weight classes ranging from 125-197 pounds, plus heavyweight. Participants completed a DXA scan during pre-season training (July 2019) and repeated DXA scan during mid-season (January 2020) 3-5 days preceding competition. Questionnaires and food records were completed during the mid-season measurement. The final end-of-season DXA measurement scheduled for March 2020 was cancelled due to COVID-19. Since the wrestling season was halted, only seven wrestlers submitted full 3-day pre-competition food records for analysis; but all questionnaire data was completed prior to this date.

Questionnaire Data

Athletes completed a survey questionnaire asking about nutritional weight cutting methods they used the week preceding competition, as well as the day of competition. Additional questions included typical weight loss during the week and day of competition. The athlete's competition weight class was recorded.

The questionnaire administered consisted of questions compiled from previous wrestling weight cutting practices by Barley, 2019, and was reviewed by the Director of Nutrition for the Ultimate Fighting Championship (UFC) Performance Institute, Clint Wattenberg. Questions pertaining to typical food intake were constructed in collaboration with Appalachian State's wrestling management staff and were reviewed by the University's Registered Sports Dietitian.

Standard 3-day food records were collected with the inclusion of a picture based protocol over a three week-day consecutive period leading up to a competition day in order to assess common macronutrient and energy intake. Participants were given instructions on how to photograph meals before and after consumption. In addition to photographs, participants were asked to send a detailed description of each meal with every picture including but not limited to: food brand name, restaurant name, time of day eaten, and cooking method used, if applicable. Beverage intake and supplement use was also recorded via picture and written description. This method of food record data collection was piloted previously with Appalachian State's wrestling team during the 2018-2019 season and results were presented at the 2019 North Carolina Academy of Nutrition and Dietetics Conference in Gastonia (Abikhaled, 2019).

In-Season Injury Data

In-season injury data was acquired from the Appalachian State Wrestling Team's Certified Athletic Trainer (ATC) with the specific injury type, location, date, and severity of each injury obtained by the wrestler throughout the competitive season. Injury data details, such as where the injury occurred (during practice or competition) and; injury characteristics, were recorded. Severity of injury was determined by the team's ATC on a three-point scale of minor, moderate, or severe. Injuries that was included for analysis were musculoskeletal injuries and concussions sustained during practice or competition throughout the 2019-2020 wrestling season. All skin lesions/lacerations and abrasions were omitted from the analysis.

DXA Whole Body Scan

Dual-energy X-ray absorptiometry (DXA) whole body scans were conducted on two occasions, the first in preseason (July 2019) and the second mid-season 3-5 day preceding a competition (January 2020) by a Horizon DXA system Hologic machine. Body composition was assessed by this instrument using a whole body x-ray technique to look at the density of different segments of the body and estimate the amount of fat mass, fat-free mass, and bone mineral content. Hydration status was acquired using Urine Specific Gravity (USG) methodology prior to performing DXA whole body scans. All twenty-eight athletes that participated in the DXA scans met the NCAA wrestling guidelines required hydration status of 1.02 or lower on the Urine Specific Gravity (USG) test administered prior to the body composition and weight assessment (NCAA Wrestling Guidelines, 2020). A third body composition measurement was scheduled for March 2020 directly following the NCAA tournament, but was cancelled due to the outbreak of COVID-19 and early termination of the wrestling season.

Data Analysis

Data were collected from twenty-eight wrestlers who completed both DXA scans and all questionnaires. Only seven wrestlers submitted full 3-day food records for analysis. Food records consisted of photos of the athlete's plate and were analyzed by the ESHA food processor software. Due to the 2020 outbreak of COVID-19, data on dietary intake was limited as the remainder of the wrestling season was cancelled. Data were analyzed for changes in body composition (body mass, fat-free mass, body fat percentage) from pre-season to mid-season and compared to body weight at the time of competition. Data from questionnaires were analyzed to characterize typical weight loss immediately preceding competition and the nutritional practices (energy restriction, fiber restriction, salt restriction, carbohydrate/glycogen depletion, passive sweating, active sweating) used to achieve competition weight goals. Specifically, changes in relation to pre-season body mass and mid-season body mass DXA scans were analyzed. Participants who experienced an injury were compared to participants who did not for body mass changes, weight loss practices and amount of weight typically lost preceding competition, and dietary intake.

Statistical Analysis

Descriptive statistics were presented for injury incidence and changes in body mass (BM), fat-free mass (FFM), and body fat percentage (BF) across the season (means ± standard deviation for all wrestlers and by competition weight class). Results from questionnaire were analyzed to calculate differences between body mass 3-5 days preceding competition and competition weight class as well as the percentage of wrestlers who reported using each method of weight loss. Total energy intake and energy intake per kg FFM were compared to Dietary Reference Intake (DRI) recommendations by the Academy of Nutrition and Dietetics. SPSS statistical software was used for all statistical calculations. Student's t-test were used to compare differences in energy intake and macronutrients between wrestlers who experienced one or more injuries vs. those who did not sustain an injury. Chi square tests were used to determine differences between weight loss method and amount of weight lost preceding competition between injured and non-injured athletes.

Chapter 3: Results

Collegiate weight classes in the United States are regulated by weight in the unit of pounds (lbs); however, body composition measurements are most often found measured in kilograms (kg). Because of this, both measurements of weight are defined in Table 1 below. Participants were separated into three divisions based on their competition weight (lbs or kg): lightweight (125, 133, 141 lbs or 56.8, 60.5, 64 kg), middleweight (149, 157, 165, 174 lbs or 67.7, 71.4, 75,79.1 kg), and heavyweight (184, 197 lbs, HWT or 83.6, 89.5 kg, HWT) according to their individual competition weight class. Of note, the heavyweight (HWT) division consists of athletes ranging from 197 to 285 lbs or 89.5 to 129.5 kg. Participants average age (years) was 20 ± 2, 20 ± 1, and 20 ± 2 yrs, respectively. Participant's weight (lbs) was measured using a Seca digital flat scale with average mean body mass of 65.5 ± 4.5, 73.6 ± 6.3, and 94.5 ± 13.2 kg, respectively. Participant's height (inches) was measured using a stadiometer with a mean height of 66 ± 1, 69 ± 2, 71 ± 2 in, respectively. Descriptive characteristics of the participants can be seen in Table 1.

Table 1.

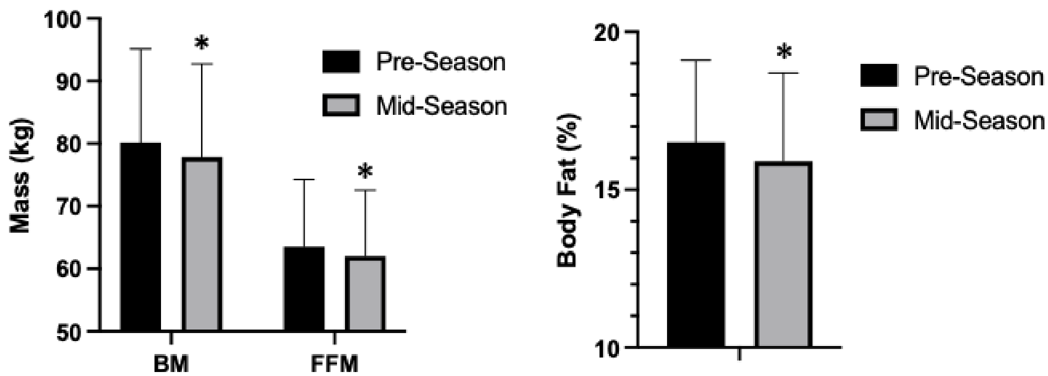
*Descriptive Data. *HWT = heavyweight, 197 to 285 pounds or 89.5 to 129.5kg.*

Descriptive Data (n=28)			
Weight Categorization	**Light (n=9)**	**Middle (n=11)**	**Heavy (n=8)**
Competition weight classes (pound)	125, 133, 141	149, 157, 165, 174	184, 197, HWT*
Competition weight classes (kilogram)	56.8, 60.5, 64	67.7, 71.4, 75,79.1	83.6, 89.5, HWT*
Age (years)	20 ± 2	20 ± 1	20 ± 2
Height (inches)	66 ± 1	69 ± 2	71 ± 2
January weight (pound)	142 ± 10	162 ± 14	208 ± 29
January weight (kilogram)	65.5 ± 4.5	73.6 ± 6.3	94.5 ± 13.2

Wrestlers significantly changed their BM over a six-month time period from pre-season to mid-season (80.2 ± 14.9 kg vs 77.9 ± 14.9 kg, $p < 0.001$). Wrestlers decreased FFM (63.5 ± 10.7 kg vs 62.0 ± 10.6 kg, $p < 0.001$) and decreased BF percentage (16.5 ± 2.6% vs 15.9 ± 2.8%, $p = 0.020$) from pre-season to mid-season DXA scans as seen in Figure 1. Nearly all participants decreased BM from pre-season to mid-season. Heavyweights experienced the greatest decrease in change BM (2.6 ± 3.8 kg), followed by lightweights change for decreased in BM (2.3 ± 3.2 kg); and lastly, the middleweight category (2.1 ± 2.8 kg). As for losses in FFM, the middleweight category changed the least with a decrease in FFM of 1.3 ± 1.0 kg, followed by the lightweight category with a decrease in FFM of 1.5 ± 2.0 kg; and the heavyweight category experienced the greatest change of FFM with a decrease of 1.9 ± 1.9 kg. Finally, we observed the lightweight category experience a decreased change of BF percentage of 0.7 ± 1.2%, followed by the middleweight category with a decrease in BF percentage of 0.6 ± 1.0%; and lastly the heavyweight category experienced the least change in decrease of BF percentage of 0.4 ± 1.6%. Ultimately, the heavyweight category had the least protective body composition changes by experiencing the greatest change of decrease of BM and FFM, while having the least change in BF percentage. Ideally, an athletes body composition changes should be reflected in relation to the change in BM, while preserving as much FFM as possible.

Figure 1.

Body Composition Analysis from pre-season to mid-season.



* indicates statistical significance $p < 0.05$ between the pre-season and mid-season measurements (n=28).

Figure 2 shows the ratio of injured to un-injured athletes. Participants were placed in the injured category if they experience one of more injuries throughout the entirety of the competitive season. Nine wrestlers experienced at least one or more injuries, and nine-teen wrestlers remained un-injured. A total of seventeen injuries were sustained throughout the entirety of the wrestling season and were defined by a ATC. Nine injuries were sustained during competition and eight injuries were sustained during practice. Of the nine wrestlers who experienced an injury; four sustained only one injury, three sustained two injuries, one sustained three injuries, and one sustained four injuries.

Figure 2.

Injured versus Un-Injured Athletes Across the Season (n=28).

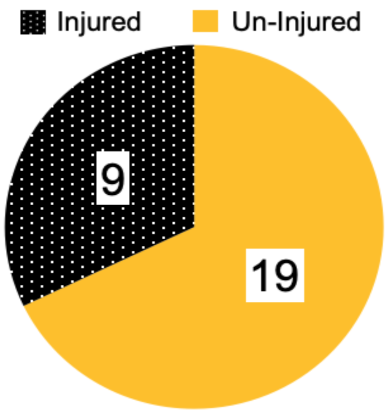


Table 2 displays the type and the total number of injuries sustained. Injuries were classified in five categories; strain, sprain, contusion, systemic, and fractures as defined by an ATC. Strain was defined as a stretching or tearing of a muscle or tendon (tissue connecting muscle to bone). Sprain was defined as a stretching or tearing of a ligament (tissue connecting bone to bone joint spaces). Contusion was defined as a direct blow to a muscle belly or ecchymosis (bleeding under the skin due to trauma). Systemic was defined as an injury spread throughout the body affecting a system's routine function. And lastly, fracture was defined as a broken or fragmented bone. The data was congruent with current literature on injuries for athletes in combat sports with sprains being the most common type, making up slightly more than half (53%) of total injuries in sport during the competitive season.

Table 2.

Number of Injuries Sustained and Type (n=9).

Injury Type	Number Sustained n (%)
Strain	3 (18%)
Sprain	9 (53%)
Contusion	3 (18%)
Systemic	1 (6%)
Fracture	1 (6%)

Figure 3 displays the severity of the injuries sustained on a scale of minor, moderate, and severe as defined by an ATC. Of the seventeen incidences of injury amongst nine wrestlers, twelve injuries were defined as minor and five injuries were defined as moderate. Collectively out of the seventeen injuries, nine injuries were sustained in competition and eight injuries were sustained during practice; however, four out of the five moderate injuries were sustained in competition. No wrestler experienced a severe injury.

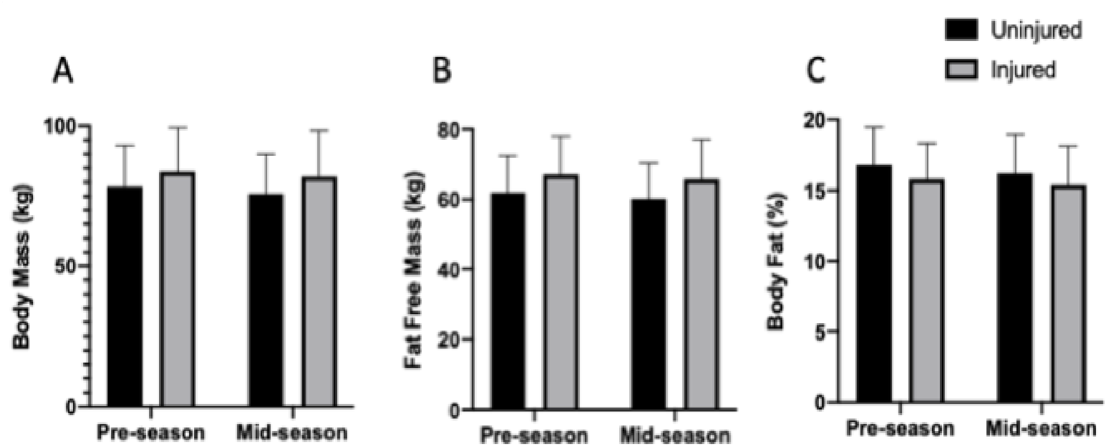
Figure 3.

Frequency and Severity of Injuries Across the Season (n=9).

Figure 4 details the body composition changes of those who experienced an injury during the season versus those who did not. Student's t-test found no significance in these body composition measurements in relation to incidence of injury (BM $t(13.9) = 0.97$, $p = 0.35$; FFM $t(27) = 1.30$, $p = 0.20$; BF $t(27) = 0.75$, $p = 0.48$). Injured wrestlers (n=9) experienced a loss in BM of 1.82 ± 0.81 kg across the season, while un-injured wrestlers (n=19) experienced a loss in BM of 2.55 ± 0.60 kg. Injured wrestlers experienced a loss of FFM of 1.27 ± 0.34 kg across the season, while un-injured wrestlers experienced a loss in FFM of 1.67 ± 0.45 kg. Injured wrestlers experienced a loss in BF percentage of 0.4 ± 0.3% across the season, while un-injured wrestlers experienced a loss in BF percentage of 0.6 ± 0.1%; however, the BF percentage of the un-injured wrestlers was the only body composition measurement where the average was higher than the injured wrestlers.

Figure 4.

Body Composition Analysis Between Injured and Un-injured (n=28).



A total body mass; **B** fat-free mass and, **C** fat mass (%).

There were no statistical differences between injured and un-injured wrestlers ($p < 0.05$).

All weight loss methods employed by the wrestlers the week and day prior to competition are reported in Tables 3 and 4, respectively, and showed no significance between injured and non-injured athletes. Active sweating was the most popular form of weight loss used in both the week (75%) and day (75%) prior to competition, followed by energy restriction used both the week (54%) and the day (50%) prior to competition, across all weight categorizations. These data do not support our hypothesis stating that the majority (>80%) of athlete's will employ the use of energy restriction in short term (3-5 days preceding competition) and long term (across season). However, our results demonstrate that energy restriction is one of the most common methods of nutritional weight practices to be used by collegiate wrestlers.

Table 3.

Weight Loss Methods employed by wrestlers the week prior to competition date.

	Weight Loss Methods Used the Week Prior to Competing		
	Lightweight (n=9) n (%)	**Middleweight (n=11) n (%)**	**Heavyweight (n=8) n (%)**
Energy Restriction	5 (56%)	6 (55%)	4 (50%)
Fiber Restriction	0 (0%)	1 (9%)	0 (0%)
Salt Restriction	2 (22%)	5 (46%)	5 (63%)
Glycogen Depletion	1 (11%)	2 (18%)	1 (13%)
Passive Sweating	0 (0%)	0 (0%)	0 (0%)
Active Sweating	8 (88%)	9 (82%)	4 (50%)
Other	1 (11%)	0 (0%)	1 (13%)

There were no statistical differences between injured and un-injured wrestlers ($p < 0.05$).

Table 4.

Weight Loss Methods employed by wrestlers the day prior to competition date.

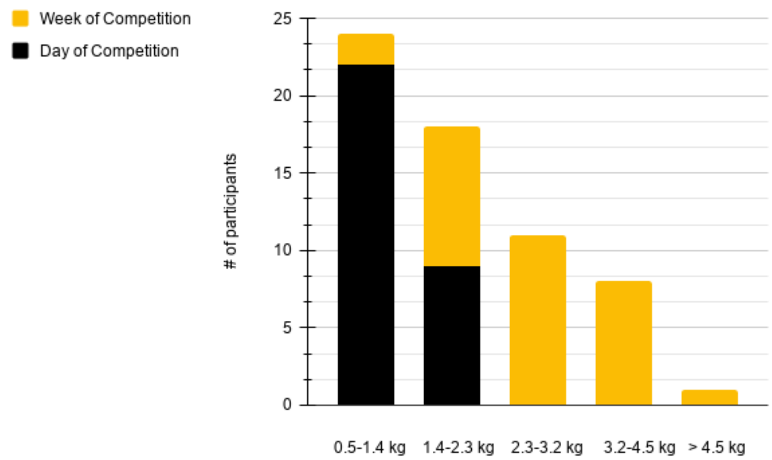
	Weight Loss Methods Used the Day Prior to Competing		
	Lightweight (n=9) n (%)	**Middleweight (n=11) n (%)**	**Heavyweight (n=8) n (%)**
Energy Restriction	6 (67%)	4 (36%)	4 (50%)
Fiber Restriction	1 (11%)	0 (0%)	0 (0%)
Salt Restriction	2 (22%)	3 (27%)	3 (38%)
Glycogen Depletion	1 (11%)	1 (9%)	2 (18%)
Passive Sweating	0 (0%)	0 (0%)	0 (0%)
Active Sweating	9 (100%)	7 (64%)	5 (63%)
Other	1 (11%)	0 (0%)	0 (0%)

There were no statistical differences between injured and un-injured wrestlers ($p < 0.05$).

Figure 5 depicts the amount of weight wrestlers reported losing in both the week and day prior to competition. Only one wrestler reported losing ten or more pounds in the week preceding the competition date. No wrestler reported losing more than five pounds the day of the competition. Results demonstrate that the majority of wrestlers, in order to make competition weight, begin losing weight the week prior to competing. No significance was found between the amount of weight lost during the week or on the day of competition in relation to incidence of injury.

Figure 5.

Amount of Weight (kg) Lost the Week and Day Preceding Competition (n=28).



There were no statistical differences between injured and un-injured wrestlers ($p < 0.05$).

The energy and macronutrient distribution obtained from the 3-day food record preceding competition day is displayed in Table 5. This dietary record was obtained in an acute weight cutting phase two days preceding competition and day of competition. There were stark nutritional differences between those who experienced injury and those who did not for kcal/kg, for kcal/kg/FFM, and for fat(g); however, they were not as expected. We hypothesized that collegiate wrestlers would employ energy restriction in the form of limiting total food intake, especially carbohydrates and fat, as a method of weight loss. The results reflect that the energy and macronutrient distribution for the total average and un-injured populations is within normal limits of the Dietary Reference Intakes (DRI) as recommended by the Academy of Nutrition and Dietetics; which are 45% to 65% carbohydrate, 10% to 35% protein, and 20% to 35% fat. For total participants, the macronutrient to energy ratio was 48% carbohydrate, 21% protein, and 31% fat. For un-injured participants, the macronutrient to energy ratio was 51% carbohydrate, 24% protein, and 25% fat. For injured participants, the macronutrient to energy ratio was 44% carbohydrate, 19% protein, and 37% fat; whereas carbohydrate is 1% below DRI and fat is 2% above DRI. We also hypothesized that collegiate wrestlers who experienced an injury, practiced greater energy restriction per kg of FFM the week preceding competition than those who do not experience an injury. This hypothesis is contrary to what the data suggest, as the un-injured wrestlers practiced greater energy restriction (19 ± 34 kcal/kg/FFM), as opposed to the injured wrestler (34 ± 7 kcal/kg/FFM). In addition, we also observed the un-injured wrestlers consumed 15 ± 28 kcal/kg, and the injured wrestlers consumed 28 ± 6 kcal/kg. Lastly, we observed that the un-injured wrestlers consumed 31 ± 13 fat (g), and the injured wrestlers consumed 101 ± 9 fat (g).

Table 5.

Energy and Macronutrient Distribution obtained three days prior to competition.

	3-Day Energy and Macronutrient Distribution		
	Total (n=7)	**Un-injured (n=5)**	**Injured (n=2)**
Kcal	1490 ± 747	1103 ± 231	2459 ± 713
Kcal/kg	19 ± 7	15 ± 28	28 ± 6
Kcal/kg FFM	23 ± 9	19 ± 34	34 ± 7
Carbohydrate (g)	179 ± 89	143 ± 37	269 ± 138
Protein (g)	81 ± 31	67 ± 23	115 ± 24
Fat (g)	51 ± 36	31 ± 13	101 ± 9

Sample size was not large enough to validate statistics.

As displayed in Table 6, the dietary data sample was not large enough to statically validate any correlation between energy and macronutrient intake related to incidence of injury. We believe that outliers in the data collected amongst injured wrestlers may also be responsible for skewing the results as both kcal/kg and kcal/kg FMM are above expected outcomes. This deserves to be investigated further as the injured sample consisted of wrestlers in heavier weight classes compared to the un-injured sample of wrestlers. It would be ideal to have a sample size consisting of an even distribution of weight classes amongst the two groups. It is likewise important to note that the total number of food records collected was small (n=7) due to data acquisition limitations caused by the COVID-19 pandemic.

Table 6.

Individual Diet Records.

	Un-injured					**Injured**	
Weight Class	Light	Middle	Middle	Middle	Middle	Middle	Heavy
Kcal	773	1258	1126	994	1363	1954	2963
Kcal/kg	13	18	15	12	20	24	32
Kcal/kg FFM	16	22	18	15	25	30	39
Carbohydrate (g)	90	155	136	143	192	172	367
Protein (g)	64	109	57	53	55	98	132
Fat (g)	18	23	40	24	49	95	108

Sample size was not large enough to validate statistics.

Chapter 4: Discussion

The purpose of this study was to investigate the acute and longitudinal nutrition practices, changes in body composition, and incidence of injuries in NCAA Division I male collegiate wrestlers across the competitive season. We aimed to explore the methods of weight loss and nutritional practices employed by wrestlers as well as the effects of these factors on the incidence for injury occurrence due to specific body composition changes.

Sport has an effect on physical traits like body mass and distribution of body composition for fat-free mass and body fat percentage. Combat sports, like wrestling, differ in competitive format and physiological requirements, which is partially reflected in athletes' physical traits. As expected due to the nature of the sport, the wrestler's training body weight measured in pre-season was greater than their body weight for competition in the mid-season measurement. The primary finding showed that wrestlers significantly decreased their BM (80.2 ± 14.9 kg vs 77.9 ± 14.9 kg, $p<0.001$), decreased FFM (63.5 ± 10.7 kg vs 62.0 ± 10.6 kg, $p<0.001$), and decreased BF (16.5 ± 2.6% vs 15.9 ± 2.8%, $p=0.020$) from pre-season to mid-season. Heavyweights experienced the greatest loss of BM (Δ 2.6 ± 3.8 kg) and the greatest loss of FFM (Δ 1.9 ± 2.0 kg). Middleweights experienced the least loss of BM (Δ 2.12 ± 2.8 kg) and the least loss of FFM (Δ 1.3 ± 2.1 kg). Ideally, an athlete's body composition changes should be reflected in relation to the change in BM, while preserving as much FFM as possible. Therefore, our results conclude that heavyweights experience the most unfavorable changes in body composition. Our findings are consistent with other studies observing a significant decrease in both total BM and FFM in college wrestlers from pre-season to post-season (Song & Cipriano, 1984). Although previous studies did not observe changes by weight classifications, we theorize that heavyweights experienced the greatest overall decrease in BM due to their larger total mass and therefore the ability to more easily manipulate greater weight changes.

In previous studies, it was found that adolescent wrestler's FFM declined from pre-season to post-season (Roemmich & Sinning, 1996). Our findings are congruent with this research as we did observe across all three weight categories that wrestlers experience significant decrease in FFM from pre-season to mid-season DXA scans. We understand that current research suggests that the preservation of FFM is beneficial for both strength and power with a possibility in reducing the risk of injury occurrence in sport (Willoughby, Hewlings, & Kalman, 2018). However, research by Utter et al. 1998, reported that college wrestlers who lose a significant amount of FFM during the competitive season were successful at maintaining both isometric muscular strength and anaerobic power, despite numerous bouts of traditional weight-cycling behavior. While it is well-known that wrestlers will most likely experience a loss of FFM over the competitive season, future research should look further into the distinct relationship of changes in body composition, specifically FFM, and the potential protective adaptabilities, like the maintenance of strength and power (which has previously been linked to reduce injury risk) in the sport of wrestling.

Of the twenty-eight athletes enrolled in this study, nine wrestlers experienced at least one injury. All injury data was obtained and verified by the wrestling team's ATC. A total of seventeen injuries were sustained throughout the season with the majority of the injuries categorized as a stretching or tearing of a ligament (tissue connecting bone and joints), otherwise known as a sprain (n=9, 53%). This was congruent with a previous systematic review by Thomas and Zamanpour, (2018) on injuries pertaining specifically to collegiate wrestlers; this study found that sprains and cartilage injuries accounted for 55% of injuries sustained. The National Collegiate Athletics Association Injury Surveillance Program likewise found sprains to be the most common type of injury sustained in the sport of wrestling, accounting for 57% of all injuries sustained (Kroshus, et al., 2018). The other injuries sustained were classified as the following: strain (n=3, 18%), contusion (n=3, 18%), systemic (n=1, 6%), and fracture (n=1, 6%). Of the seventeen total injuries sustained, nine (53% of them) occurred during competition and eight (47% of them) occurred in practice. Results in our study depicted an even spread of when injury occurred (whether in practice or competition) as compared to other literature. The National Collegiate Athletics Association Injury Surveillance Program among division one wrestlers found that 71% (n=914) were sustained during practice, and 29% (n=381) were sustained during competition (Kroshus, et al., 2018). Mitigating injury minimizes risk associated with the effects enacted by time spent away from the sport and should be studied further to clarify the understanding of risk factors for injury occurrence.

Despite finding a total significant change in body composition, there was no significance found between the pre-season and mid-season body composition (BM, FFM, BF) in injured versus un-injured wrestlers. The injured wrestlers experience a smaller change in decreasing BM from pre-season to mid-season (Δ 1.8 ± 0.8 kg) compared to the un-injured wrestlers (Δ 2.5 ± 0.6 kg). For FFM, the injured wrestlers also experienced a smaller change in decreasing FFM (Δ 1.3 ± 0.4 kg), compared to the injured wrestlers (Δ 1.7 ± 0.5 kg). These data do not support our second hypothesis that collegiate wrestlers who experienced an injury lost more BM and FFM than those who do not have an injury. The incidence of injury is not only affected by body composition changes like loss of FFM, but also the nutritional practices in which athletes employ to manipulate mass preceding competition. With such magnitude of rapid weight loss, including loss of FFM, protective measures against injury incidence are hypothesized to be reduced with sound nutritional practices (Thomas & Zamanpour, 2018).

It is well-known that wrestling is a combat sport in which athletes will use methods of acute weight loss in order to compete in predetermined weight classes. It is most often advantageous for wrestlers to be near their competition weight in the week preceding competition in order to achieve a more manageable weight loss for the day of competition (Reale, et al., 2017). A number of weight cutting practices may be used including: energy restriction, fiber restriction, salt restriction, glycogen depletion, passive and active sweating, or other methods such as fat burners and laxatives (Reale, Slater, & Burke, 2017). These methods may be used singularly or in combination with one another. Our results found the most common nutritional practices used by wrestlers both acute and longitudinally was active sweating in both the week (75%) and day (75%) prior to competition, followed by energy restriction used both the week (54%) and the day (50%) prior to competition, across all weight categorizations. The majority (>80%) of wrestlers surveyed used at least two methods of weight loss synonymously. Our data are congruent with current literature stating that energy restriction is one of the most common nutritional methods of weight cutting with 57% of wrestlers surveyed using energy restriction the week preceding competition (Rankin, et al., 1996). While the results did not support our hypothesis that the majority (>80%) of wrestlers use energy restriction as a form of weight loss, our results provide insight to some of the most common methods of nutritional weight practices used by collegiate wrestlers today; as no study, to our knowledge, has yet to explore the potential link of weight loss methods to incidence of injury.

When exploring energy balance in relation to the macronutrient distribution of a three-day dietary record of wrestlers preceding competition day, we found the un-injured wrestlers practicing greater energy restriction (19 ± 34 kcal/kg/FFM), as opposed to the injured wrestlers (34 ± 7 kcal/kg/FFM). These data are contrary to our hypothesis that collegiate wrestlers who experienced an injury, practiced greater energy restriction per kg of FFM the week preceding competition than those who do not experience an injury. In addition, we also observed a difference between wrestler's kcal/kg between un-injured vs injured wresters (15 ± 28 vs g 28 ± 6 kcal/kg). We observed differences in dietary fat intake between un-injured and injured wrestlers (31 ± 13 vs 101 ± 9 g fat), While un-injured participant's macronutrient to energy ratio met the DRI (51% carbohydrate, 24% protein, and 25% fat); the injured participant's carbohydrate was 1% below DRI and fat was 2% above DRI (44% carbohydrate, 19% protein, and 37% fat). However, we did observe a slight restriction in carbohydrates (1% below DRI). This data, while the sample size was not large enough to validate statistically, disproved our hypothesis that injured wrestlers would employ greater energy restriction in the form of limiting total food intake, especially fat, as a method of weight loss. For total participants, the macronutrient to energy ratio was 48% carbohydrate, 21% protein, and 31% fat; which is closer to the DRI reference intakes than other literature suggests. One study of Australian Olympic athletes in 1996, which includes male and female athletes of various sport disciplines (endurance, sprint/skill, team, combat-sports), suggested that eating patterns from a 7-day dietary recorded provided a macronutrient to energy ratio of 55% carbohydrate, 28% fat, and 17% protein (Burke et al., 2003). Another study found that elite collegiate wrestlers, when in acute weight loss periods, practiced an energy restriction of 1071 ± 536 kcals per day and 14.5 ± 6.9 kcal/kg (Kondo et al., 2018). Comparatively, the wrestlers in our study, also during a period of acute weight loss preceding competition, on average practiced more liberal energy restriction methods of 1490 ± 747 kcals per day and 19 ± 7 kcal/kg. It is possible that the differences indicated may be due to the practice of appropriate weight management by wrestlers in our study. It is likewise important to note that the total number of food records collected was small (n=7) and may contain outliers skewing the energy and macronutrient data amongst the injured wrestlers. Data acquisition limitations caused by the COVID-19 pandemic are also to blame for the inadequate sample size of dietary records collected. We were not able to compare differences by weight class due to the limited sample size and the lack of sufficient data. These limitations contribute to the unfavorable conclusions between the injured and un-injured wrestlers.

In summary, we found significant changes in overall BM, FFM, and BF percentage from pre-season to mid-season, but no differences by injury. Restrictive dietary intake and weight-cutting methods were not linked to incidence of injury. While losing fat mass while maintaining potentially protective lean muscle mass is possible, it takes strategizing to be done correctly. Nutritionally, a small calorie deficit should be made over a substantial amount of time (beginning in pre-season) prior to mid-season competition weight. Large energy restriction will result in acute weight loss, but some of that loss can be in the form of lean muscle (Willoughby, Hewlings, & Kalman, 2018). Slower rates of weight loss will help better preserve lean muscle mass in athletes; however, the specific amount of energy restriction will vary based on gender, weight, and activity level of the athlete (Lowe, Doshi, Katterman, & Feig, 2013). A small calorie deficit, beginning in pre-season, should be made over a substantial amount of time prior to competition in order to most effectively optimized body composition for sport (Reale, et al., 2017). Current research also shows that prioritizing a diet high in protein (1.6 to 2.2 g/kg/day) can reduce fat mass while preserving lean muscle mass (Morton, et al., 2017). As for the acute recovery period in between weigh-ins and competition, athletes should focus on replenishing depleted glycogen stores with 5–10 g/kg/day carbohydrate (Barley et al., 2019). In addition to the recovery of muscle glycogen after weigh-ins, athletes need to consider their total body water and electrolyte balance. Athletes, especially in weight-class sports, should seek the expertise of a Registered Dietitian when employing the use of energy restriction as a potential weight cutting method in order to optimize performance in sport and mitigate the negative health implications associated with poor nutrition practices and weight cycling.

Unfortunately, our data are limited by early season termination due to COVID-19 and the small number of collected food records. Future research should focus on dietary interventions to manipulate body composition to determine a relationship between nutrition and injury risk.

References

Abikhaled, Sophie. (2019). Collegiate Wrestlers Meet Acceptable Macronutrient Distribution Ranges, But Not Energy Needs, During Pre-Season Training. North Carolina Academy of Nutrition and Dietetics Conference, Charlotte NC, March 2019. Appalachian State University, Boone, 2019. Print.

Agel, J., Ransone, J., Dick, R., Oppliger, R., & Marshall, S. W. (2007). Descriptive epidemiology of collegiate men's wrestling injuries: National Collegiate Athletic Association Injury Surveillance System, 1988-1989 through 2003-2004. *Journal of athletic training*, 42(2), 303–310.

Barley, O., Chapman, D., & Abbiss, C. (2019). The Current State of Weight-Cutting in Combat Sports. *Sports*, 7(5), 123. https://doi.org/10.3390/sports7050123

Bartlett, J. D., Hatfield, M., Parker, B. B., Roberts, L. A., Minahan, C., Morton, J. P., & Thornton, H. R. (2019). DXA-derived estimates of energy balance and its relationship with changes in body composition across a season in team sport athletes. *European Journal of Sport Science*, 20(7), 859–867. https://doi.org/10.1080/17461391.2019.1669718

Burke, L. M., Slater, G., Broad, E. M., Haukka, J., Modulon, S., & Hopkins, W. G. (2003). Eating Patterns and Meal Frequency of Elite Australian Athletes. *International Journal of Sport Nutrition and Exercise Metabolism*, 13(4), 521–538. https://doi.org/10.1123/ijsnem.13.4.521

Dryden, S. V., Shoemaker, W. G., & Kim, J. H. (2013). Wound Management and Nutrition for Optimal Wound Healing. *Atlas of the Oral and Maxillofacial Surgery Clinics,* 21(1), 37–47. https://doi.org/10.1016/j.cxom.2012.12.008

Ekstrand, J., Krutsch, W., Spreco, A., van Zoest, W., Roberts, C., Meyer, T., & Bengtsson, H. (2019). Time before return to play for the most common injuries in professional football: a 16-year follow-up of the UEFA Elite Club Injury Study. *British Journal of Sports Medicine,* 54(7), 421–426. https://doi.org/10.1136/bjsports-2019-100666

Emery, C. A. (2009). Injury prevention in paediatric sport-related injuries: a scientific approach*. British Journal of Sports Medicine*, 44(1), 64–69. https://doi.org/10.1136/bjsm.2009.068353

Finn, K. J., Dolgener, F. A., & Williams, R. B. (2004). Effects of carbohydrate refeeding on physiological responses and psychological and physical performance following acute weight reduction in collegiate wrestlers. *Journal of strength and conditioning research,* 18(2), 328– 333. https://doi.org/10.1519/R-13062.1

Franchini, E., Brito, C. J., & Artioli, G. G. (2012). Weight loss in combat sports: physiological, psychological and performance effects. *Journal of the International Society of Sports Nutrition*, *9*(1). https://doi.org/10.1186/1550-2783-9-52

Hargreaves, M. (2015). Exercise, muscle, and CHO metabolism. *Scandinavian Journal of Medicine & Science in Sports*, *25*, 29–33. https://doi.org/10.1111/sms.12607

Janssen, I. (2007). Physical activity guidelines for children and youth. This article is part of a supplement entitled Advancing physical activity measurement and guidelines in Canada: a scientific review and evidence-based foundation for the future of Canadian physical activity guidelines co-published by Applied Physiology, Nutrition, and Metabolism and the Canadian Journal of Public Health. It may be cited as Appl. Physiol. Nutr. Metab. 32(Suppl. 2E) or as Can. J. Public Health 98(Suppl. 2). *Applied Physiology, Nutrition, and Metabolism*, *32*(S2E). https://doi.org/10.1139/h07-109

Kondo, E., Sagayama, H., Yamada, Y., Shiose, K., Osawa, T., Motonaga, K., Ouchi, S., Kamei, A., Nakajima, K., Higaki, Y., Tanaka, H., Takahashi, H.,Okamura, K. (2018). Energy deficit required for rapid weight loss in elite collegiate wrestlers. *Nutrients, 10*(5), 536. doi:http://dx.doi.org/10.3390/nu10050536

Kroshus, E., Utter, A. C., Pierpoint, L. A., Currie, D. W., Knowles, S. B., Wasserman, E. B., Kerr, Z. Y. (2018). The First Decade of Web-Based Sports Injury Surveillance: Descriptive Epidemiology of Injuries in US High School Boys' Wrestling (2005–2006 Through 2013–2014) and National Collegiate Athletic Association Men's Wrestling (2004–2005 Through 2013–2014). *Journal of Athletic Training*, *53*(12), 1143–1155. https://doi.org/10.4085/1062-6050-154-17

Longland, T. M., Oikawa, S. Y., Mitchell, C. J., Devries, M. C., & Phillips, S. M. (2016). Higher compared with lower dietary protein during an energy deficit combined with intense exercise promotes greater lean mass gain and fat mass loss: a randomized trial. *The American Journal of Clinical Nutrition*, 103(3), 738–746. https://doi.org/10.3945/ajcn.115.119339

Lowe, M. R., Doshi, S. D., Katterman, S. N., & Feig, E. H. (2013). Dieting and restrained eating as prospective predictors of weight gain. *Frontiers in Psychology*, *4*. https://doi.org/10.3389/fpsyg.2013.00577

Malm, C., Jakobsson, J., & Isaksson, A. (2019). Physical Activity and Sports—Real Health Benefits: A Review with Insight into the Public Health of Sweden. *Sports*, *7*(5), 127. https://doi.org/10.3390/sports7050127

Marra, M., Sammarco, R., De Lorenzo, A., Iellamo, F., Siervo, M., Pietrobelli, A., Contaldo, F. (2019). Assessment of Body Composition in Health and Disease Using

Bioelectrical Impedance Analysis (BIA) and Dual Energy X-Ray Absorptiometry (DXA): A Critical Overview. *Contrast Media & Molecular Imaging*, *2019*, 1–9. https://doi.org/10.1155/2019/3548284

Montgomery, M. M., Shultz, S. J., Schmitz, R. J., Wideman, L., & Henson, R. A. (2012). Influence of Lean Body Mass and Strength on Landing Energetics. *Medicine & Science in Sports & Exercise*, *44*(12), 2376–2383. https://doi.org/10.1249/mss.0b013e318268fb2d

Morton, R. W., Murphy, K. T., McKellar, S. R., Schoenfeld, B. J., Henselmans, M., Helms, E., Aragon, A., Devries, M., Banfield, L., Krieger, J., Phillips, S. (2017). A systematic review, meta-analysis and meta-regression of the effect of protein supplementation on resistance training-induced gains in muscle mass and strength in healthy adults. *British Journal of Sports Medicine*, *52*(6), 376–384. https://doi.org/10.1136/bjsports-2017-097608

Mountjoy, M., Sundgot-Borgen, J., Burke, L., Ackerman, K. E., Blauwet, C., Constantini, N., Budgett, R. (2018). International Olympic Committee (IOC) Consensus Statement on Relative Energy Deficiency in Sport (RED-S): 2018 Update. *International Journal of Sport Nutrition and Exercise Metabolism*, *28*(4), 316–331. https://doi.org/10.1123/ijsnem.2018-0136

NCAA Wrestling Rules of the Game. (2020, December 8). Wrestling Rules of the Game. NCAA.org - The Official Site of the NCAA. http://www.ncaa.org/playing-rules/wrestling-rules-game.

Nédélec, M., McCall, A., Carling, C., Legall, F., Berthoin, S., & Dupont, G. (2012). Recovery in Soccer. *Sports Medicine*, *42*(12), 997–1015. https://doi.org/10.2165/11635270-000000000-00000

Pfeifer, C. E., Beattie, P. F., Sacko, R. S., & Hand, A. (2018). Risk Factors Associated With Non-Contact Anterior Cruciate Ligament Injury: A Systematic Review. *International Journal of Sports Physical Therapy*, *13*(4), 575–587. https://doi.org/10.26603/ijspt20180575

Quarrie, K. L. (2001). The New Zealand rugby injury and performance project. VI. A prospective cohort study of risk factors for injury in rugby union football. *British Journal of Sports Medicine*, *35*(3), 157–166. https://doi.org/10.1136/bjsm.35.3.157

Rankin, J. W., Ocel, J. V., & Craft, L. L. (1996). Effect of weight loss and refeeding diet composition on anaerobic performance in wrestlers. *Medicine & Science in Sports & Exercise*, *28*(10), 1292–1299. https://doi.org/10.1097/00005768-199610000-00013

Reale, R., Slater, G., & Burke, L. (2017). Individualised dietary strategies for Olympic combat sports: Acute weight loss, recovery and competition nutrition. *European Journal of Sport Science*, *17*(6), 727–740. https://doi.org/10.1080/17461391.2017.1297489

Reale, R., Slater, G., & Burke, L. M. (2017). Acute-Weight-Loss Strategies for Combat Sports and Applications to Olympic Success. *International Journal of Sports Physiology and Performance*, *12*(2), 142–151. https://doi.org/10.1123/ijspp.2016-0211

Rodriguez, N. R., DiMarco, N. M., Langley, S., (2009). Position of the American Dietetic Association, Dietitians of Canada, and the American College of Sports Medicine:

Nutrition and Athletic Performance. (2009). *Journal of the American Dietetic Association*, *109*(3), 509–527. https://doi.org/10.1016/j.jada.2009.01.005

Roemmich, J., & Sinning, W. (1996). Sport-Seasonal Changes in Body Composition, Growth, Power and Strength of Adolescent Wrestlers. *International Journal of Sports Medicine*, *17*(02), 92–99. https://doi.org/10.1055/s-2007-972814

Schneider, D. A., & Trence, D. L. (2019). Possible Role of Nutrition in Prevention of Sarcopenia and Falls. *Endocrine Practice*, *25*(11), 1184–1190. https://doi.org/10.4158/ep-2019-0144

Silva, A. M., Matias, C. N., Santos, D. A., Thomas, D., Bosy-Westphal, A., Müller, M. J., Sardinha, L. B. (2017). Energy Balance over One Athletic Season. *Medicine & Science in Sports & Exercise*, *49*(8), 1724–1733. https://doi.org/10.1249/mss.0000000000001280

Steen, S. N., & Brownell, K. D. (1990). Patterns of weight loss and regain in wrestlers. *Medicine & Science in Sports & Exercise*, *22*(6), 762. https://doi.org/10.1249/00005768-199012000-00005

Song, T.M.K., & C. Cipriano. (1984). Effects of Seasonal Training on Physical and Physiological Function on Elite Varsity Wrestlers. *Journal of Sports Medicine*, 1984, pp. 24:123–130.

Sundgot-Borgen, J., Meyer, N. L., Lohman, T. G., Ackland, T. R., Maughan, R. J., Stewart, A. D., & Müller, W. (2013). How to minimise the health risks to athletes who compete in weight-sensitive sports review and position statement on behalf of the Ad Hoc Research Working Group on Body Composition, Health and Performance, under the auspices of the IOC Medical Commission. *British Journal of Sports Medicine*, *47*(16), 1012–1022. https://doi.org/10.1136/bjsports-2013-092966

Thomas, R. E., & Zamanpour, K. (2018). lnjuries in wrestling: systematic review. *The Physician and Sportsmedicine*, *46*(2), 168–196. https://doi.org/10.1080/00913847.2018.1445406

Utter, A., Stone, M., O'Bryant, H., Summinski, R., & Ward, B. (1998). Sport-Seasonal Changes in Body Composition, Strength, and Power of College Wrestlers. *Journal of Strength and Conditioning Research*, *12*(4), 266–271. https://doi.org/10.1519/00124278-199811000-00012

Wild, T., Rahbarnia, A., Kellner, M., Sobotka, L., & Eberlein, T. (2010). Basics in nutrition and wound healing. *Nutrition*, *26*(9), 862–866. https://doi.org/10.1016/j.nut.2010.05.008

Willoughby, D., Hewlings, S., & Kalman, D. (2018). Body Composition Changes in Weight Loss: Strategies and Supplementation for Maintaining Lean Body Mass, a Brief Review. *Nutrients*, *10*(12), 1876. https://doi.org/10.3390/nu10121876

Zubac, D., Paravlic, A., Reale, R., Jelaska, I., Morrison, S. A., & Ivancev, V. (2019). Fluid balance and hydration status in combat sport Olympic athletes: a systematic review with meta-analysis of controlled and uncontrolled studies. *European Journal of Nutrition*, *58*(2), 497–514. https://doi.org/10.1007/s00394-019-01937-2

Vita

Tyler Roof was born in Atlanta, Georgia, to Robin and Todd Roof. She graduated from Hebron Christian Academy in 2015, after which, she attended the University of Georgia where she received a Bachelor of Science in Dietetics in the Spring of 2019. She then began her studies at Appalachian State University in the Fall of 2019, where she worked as a Graduate Assistant in the Department of Wellness and Prevention Services. The following year, she completed her Dietetic Internship in Asheville, NC. She will be awarded the Master of Science degree in Nutrition and Dietetics in May of 2021 from Appalachian State University.