NUTRIENT INTAKE, PERFORMANCE, AND BODY COMPOSITION IN PRESEASON WRESTLERS

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This thesis is approved as a creditable and independent investigation by a candidate for the master's degree and is acceptable for meeting the thesis requirements for this degree. Acceptance of this does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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CONTENTS

ABSTRACT

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BACKGROUND: College athletes, especially in weight class sports, often experience energy deficits. Weight class sports such as wrestling are at greatest risk for deficiencies, and little is known about the relationships between body composition, nutrient intake, and performance in these athletes. **OBJECTIVES:** The purposes of this study were to quantify macronutrient and micronutrient intake of pre-season male collegiate wrestlers and compare to recommendations, and examine relationships among nutritional intakes, body composition, and performance measurements of strength, anaerobic, and aerobic capacity. **METHODS:** Male Division I wrestlers (n=11, mean ± SD age: 21.3±1.7 years, wrestling experience: 14.9±2.5 years) were recruited during pre-season. Nutrient intake was collected from a 3-day food diary. A 7-site skinfold assessment determined fat-free mass (FFM) to estimate total energy expenditure. Isokinetic and isometric strength was evaluated by a Biodex dynamometer. Aerobic and anaerobic capacity were tested on a stationary cycle ergometer. **RESULTS:** Eight of eleven wrestlers were energy deficient based on estimated needs. Mean intake for 4 micronutrients fell below the RDA. Significant correlations were found between energy and macronutrient intake, and strength and anaerobic performance variables (r=0.603 – 0.902, p=0.0001 – 0.05). However, after accounting for FFM, these relationships were no longer significant. **CONCLUSIONS:** Nutrient intake in tandem with body composition effect performance for weight class athletes. Maintaining high FFM, especially during the competition season, may be advantageous for wrestling performance. Nutrient intake and body composition should be monitored so coaches and health professionals can create individualized recommendations to help athletes optimize performance.

CHAPTER I: Introduction

Student athletes have demonstrated an increased need for energy intake, particularly during a competition season.[1] Despite this elevated demand, many athletes have been found to be in negative energy balance.[2,3] For example, Zanders et al. found that while energy balance did not change significantly throughout the season for female collegiate basketball players, they were in negative energy balance during each phase.[3] Similarly, Silva et al reported that the mean energy balance for basketball, volleyball, handball players, triathletes and swimmers was negative during the season, and total energy expenditure increased by 15.7%.[2] Overall, while body composition changes differ depending on the type of sport and sex of the athlete, changing energy expenditure and intake levels throughout a season may be accompanied by shifts in body composition. While important to monitor in all athletes, those needing to perform at a certain weight are at greater risk of being in a negative energy balance, therefore leading to inadequate energy, macronutrient, and micronutrient intake to support the demands of the sport.

Athletes' failure to meet nutritional needs may be due to lack of knowledge regarding their energy needs and intake levels. Jagim et al., reported that NCAA Division III athletes (wrestling, football, soccer, volleyball, and track and field) significantly underestimate daily energy, carbohydrate, and fat needs ($p \leq 0.01$).[4] Furthermore, low diet quality has been reported among the collegiate athlete population. Specifically, poor quality of fatty acids, and whole grain foods has been reported, notably in athletes at a university where athlete-focused nutrition support is available.[5] Among these athletes, diet quality is particularly low during the off-season, when nutrition support is not available. Additionally, when comparing sports teams, the lowest diet quality was found in wrestling, with a higher intake of convenience foods containing high fat and sodium.[5] Furthermore, weight sensitive sports had the highest prevalence of extreme weight control behaviors.[6] These findings indicate that wrestlers may be at risk for energy, macronutrient, and micronutrient deficiencies.

In addition, previous studies report low vitamin D status in wrestlers,[7,8] as well as insufficient biotin (34.9% of RDA), zinc (79% of RDA), and iodine (13.85% of RDA) intakes.[8] While there has not been sufficient research performed to associate any micronutrient deficiencies with particular health or performance risks for this population, considering the role multiple micronutrients have on skeletal muscle performance, including vitamin D and biotin, low status is a concern. For example, vitamin D plays a major role in bone repair, development, and maintenance, while biotin takes part in energy metabolism, as well as tissue repair and maintenance.[9,10] Additionally, many other micronutrients play a large role in athletic performance for energy production, oxygen transport, and muscle contraction, and are known to be deficient in athletes, particularly in sports that have to restrict energy intake or utilize severe or rapid weight loss (RWL) strategies.[9] A similar pattern in wrestlers is likely, particularly with the compounded risk of being in a negative energy balance. Monitoring wrestlers' dietary intakes can help better define the prevalence of poor dietary patterns and create solutions for this population to improve their body composition and performance goals within the wrestling season. Determining nutritional intake, as well as how it relates to body composition and performance, will provide guidance for recommendations at different phases of the season.

Numerous physiological factors have been found to impact wrestling performance, including anaerobic, aerobic, strength, and agility variables. Several early studies in wrestlers examined anaerobic and aerobic capacity,[11–15] as well as strength,[16,11] and even flexibility,[11] to provide a profile of measurements that may be useful to evaluate wrestling performance. Furthermore, specific performance outcomes have been found to predict wrestling success or competitive level, in which measures of anaerobic and aerobic capacity, flexibility, and training experience,[17] as well as technical wrestling skills, endurance, and agility variables were found to be important predictors.[18] Demirkan et al. reported that anaerobic power, flexibility, $\dot{V}O_{2max}$, and training experience (defined as number of years of participation in wrestling) had an 84.8% prediction accuracy of classifying athletes as either elite or amateur.[17] While these studies provide a foundation for expectations of wrestling performance, few studies have compared body composition and performance variables, despite evidence that body composition changes throughout a wrestling season. In fact, body mass (bm) and body fat percentage (BF%) were reported to decrease up to 3.6 kg and 2.6%, respectively, over the wrestling season.[19]

Body composition has been shown to influence performance measurements in wrestlers, with a positive correlation between fat free mass (FFM) and mean anaerobic power ($r = 0.73$, $p \leq 0.05$).[14] It is also known that FFM is associated with strength, and overall physical performance.[20–22] Many athletes, including wrestlers, may wish to lower their total body mass, while preserving FFM in order to optimize their body composition for performance. This highlights the need to examine relationships between body composition and performance measurements at different phases of the season and determine how nutrition may be related to these markers, to best provide recommendations for improved body composition and performance throughout the season.

Along with longitudinal changes of anthropometric measurements, wrestling training has been shown to influence short term changes in metabolism. Papassotiriou et al. reported that lactate concentrations increased acutely from pre- to post-training after a single wrestling practice (2.0 $mmol \cdot L^{-1}$ to 5.5 $mmol \cdot L^{-1}$) ($p < 0.001$), indicating a reliance on anaerobic metabolism for wrestling training and performance [23] The wrestlers with greater experience demonstrated greater lactate levels after a training bout which may show differences between anaerobic capacity abilities in starting versus non-starting wrestlers that could influence training and nutrition recommendations. Additionally, the authors concluded that lactate concentration was elevated above the lactate threshold after training sessions, promoting gluconeogenesis, thus potentially leading to greater work capacity.[23] Improvement of the lactate threshold can benefit performance by sparing muscle glycogen and reducing fatigue.[24] However, research has suggested that high level athletes may see a decline in lactate threshold during the competition season, suggesting performance decrements over the season.[25] Further research is needed to fully understand the influence of nutrition on lactate concentrations and how that relates to aerobic and anaerobic performance measurements. Additionally, evaluating how nutrient intake interacts with these variables is necessary to provide nutrition and training recommendations prior to wrestlers entering their competition season to best support the athlete with any nutritional and body composition changes necessary during the season.

A major nutritional concern with wrestling is that it is a weight class sport, meaning many athletes engage in RWL behaviors prior to a competition. While the exact methods of RWL vary depending on the athlete, the most common behaviors include dieting, increased exercise, and dehydration.[26] Techniques for RWL have been shown to present with physiological symptoms such as lack of urine and tears, fatigue, and confusion, as well as influencing mood of wrestlers and taekwondo athletes.[27]

Despite the high prevalence of partaking in RWL techniques, many athletes perceive RWL to have a negative influence on performance.[27] However, it is not well known how dietary-based RWL techniques affect performance. Previous research has demonstrated that many successful high-level wrestlers and other combat sport athletes engage in dehydration practices. While dehydrated athletes had lower performance measurements (mean power velocity of the bench press and counter-movement jump power) compared to euhydrated athletes pre-weigh ins, the more dehydrated athletes demonstrated a greater increase in muscle power velocity of the bench press (7.3% versus -3.4%) and jump power (2.8% versus 1.1%) after weigh ins than euhydrated athletes ($p<0.001$). This provides evidence that dehydration can reduce neuromuscular performance, but athletes are able to recover quickly.[28] Additionally, Kondo et al., suggests that short term (53 hours) energy restriction of up to 7700 $kcal \cdot kg\Delta BM^{-1}$ should be harmless considering most of the body mass lost during this period can be attributed to total body water (71%).[29] These findings suggest that RWL can be achieved in a non-harmful way, but more research is needed to determine an optimal approach for performance and body composition long term, particularly prior to the competition season.

One method that may be valuable for wrestlers during times of energy deficit is high protein intake, as an intake up to 2.4 $g \cdot kg^{-1}$ of daily protein has been shown to help preserve lean body mass.[30,31] Moreover, a low carbohydrate diet may aid wrestlers in making weight. Although a low carbohydrate diet may lower anaerobic performance values, athletes have been able to recover anaerobic power after implementing a high carbohydrate diet.[32] This method could coincide with the suggestion by Close et al., that athletes in weight class sports cycle their energy intake so as to avoid long term low energy availability.[31] Still, athletes will have to be careful how they implement these strategies as exact recommendations are lacking. Previous research has shown that three carbohydrate meals of 7.1 $g \cdot kg^{-1}$ of body weight during a thirteen hour period was not enough to restore muscle glycogen lost from a six percent RWL,[33] indicating that long-term nutritional strategies may be more effective. However, to provide recommendations for RWL, assessments of current nutritional intake in wrestlers is necessary.

Many collegiate wrestlers choose to use the pre-season to adjust their nutritional intake and lose weight in order to be closer to their chosen weight class. If done optimally, this can set athletes up for a successful competition season; however, without nutritional guidance, it is likely that nutritional requirements for competition season, body composition, and performance goals are not being met. In order to provide recommendations to best fit the physiological demands of the sport of wrestling, more research on the nutrient intake of these athletes is needed. Determining how nutrient intake is related to performance and body composition measurements is a necessary step to understand how diet can be utilized to impact performance and body composition based on the needs of the sport. Therefore, the aims of this study are to (1): quantify macronutrient and micronutrient intake of pre-season male collegiate wrestlers and compare to recommendations, and (2): examine relationships among nutritional intakes, body composition, and performance measurements of strength, anaerobic, and aerobic capacity. We hypothesize that overall, collegiate wrestlers will not meet recommendations for macronutrient distribution and micronutrient intake but will have adequate energy intake. Additionally, we hypothesize that there will be positive relationships between nutritional intake and measurements of body composition and performance.

CHAPTER II: Literature Review

Nutrient Status of Athletes

Longland et al., 2016

The purpose of this study was to evaluate whether a higher protein diet (PRO) or a lower protein diet (CON) during energy deficit would reduce the loss or aid the gain of lean body mass (LBM) while resistance training (RT), high-intensity interval training/sprint interval training (HIT/SIT) were performed. The study consisted of forty males, with a mean age of 23 ±2 years old, all of whom were recreationally active. Participants were assigned to either the higher protein diet group (PRO), consuming 2.4 $g \cdot kg^{-1}$ of protein daily, or the control group (CON), consuming 1.2 $g \cdot kg^{-1}$ of protein daily. All meals and beverages were provided to participants throughout the experimental period. All participants underwent exercise training six days per week at the laboratory for four weeks. Body composition, maximal aerobic capacity (VO_{2max}), peak anaerobic capacity, isometric maximal voluntary contraction, and voluntary isotonic strength were measured before, and after completion of the four week intervention. Both groups experienced weight loss, with no difference in amount of weight lost between groups. For the CON group, LBM did not change but increased in the PRO group by 1.2±1.0 kg ($p \leq 0.05$). Additionally, the PRO group experienced greater loss of fat mass than the CON group (-4.8±1.6 kg compared to -3.5±1.4 kg). Both groups increased all performance based variables, excluding isometric knee extension torque, but no differences between groups was calculated. The authors conclude that protein intake up to three times greater than the RDA during a four week energy deficit, and high intensity training, may preserve and increase lean body mass in young males. This study indicates that it may be beneficial for athletes to increase their protein intake, particularly when undergoing weight loss, to preserve lean body mass, and strength. Examining performance and nutrient intake in specifically athletes will allow researchers to explore if the results from this study translate into an athlete population.

Michalczyk et al., 2019

The purpose of this study was to analyze whether a four week low carbohydrate diet (LCD), and subsequent high carbohydrate diet (HCHO-D) affects anaerobic performance. The subjects consisted of 15 male basketball players competing in the Polish Basketball League. The mean age of participants was 23.5±2.2 years, and all participants had at least five years of training experience. For four weeks, participants were fed a LCD consisting of 10% carbohydrates, 31% protein, and 59% fat. Following those four weeks, participants were given a HCHO-D for one week, consisting of 75% carbohydrates, 16% protein, and 9% fat. Body composition was assessed using bioelectrical impedance analysis, and a 30 second Wingate test for lower limbs analyzed anaerobic capacity. Lactate concentration and acid-base equilibrium was assessed with fingertip capillary blood samples, taken at rest, and after three minutes of recovery. Measurements were taken three times over the course of the five week experiment: at baseline before the LCD, after the LCD, and after the HCHO-D. A significant difference of fat free mass (FFM) was found when comparing LCD (78.20±3.65 kg) and HCHO-D (79.92±3.84 kg) ($p < 0.05$). Additionally, after the HCHO-D, total work values of the Wingate test were significantly higher than after the LCD (302.46±8.50 $J \cdot kg^{-1}$ and 266.69±6.46 $J \cdot kg^{-1}$, respectively, $p = 0.021$). Lactate concentration at rest was significantly higher after HCHO-D (1.69±0.04 mmol·L^{-1}) when compared to LCD (1.26±0.01 mmol·L^{-1}). The authors conclude that LCD to supply an alternative fuel source, followed by carbohydrate refeeding does not appear to offer benefits to anaerobic performance. However, for sports that engage in rapid weight loss, such as wrestling and martial arts, LCD can be implemented to aid that process, and anaerobic power is able to be recovered after carbohydrate loading. Further research is needed to better understand the effects of different diets on additional factors of performance, such as aerobic capacity and strength.

Barcal et al., 2016

The purpose of this study was to analyze the relationship of low vitamin D status and cases of acute illness, skin infections, and inflammatory cytokines of male collegiate wrestlers. Additionally, an evaluation of the impact of weight and body composition changes on vitamin D and cytokine concentration was made. This study consisted of 19 male collegiate wrestlers, all members of the University of Wyoming wrestling team. Measurements were taken three times throughout the academic year, in September, January, and April. Blood was drawn, and a questionnaire was used to assess vitamin D status. Height and weight were taken, and dual energy x-ray absorptiometry was used to assess body composition. Routine injury, illness, and skin infection data was collected by the team physician and recorded in the student-athlete medical charts. A total of 19 participants completed baseline vitamin D evaluation; however, longitudinal vitamin D data was available for only 16 participants, and longitudinal body composition and cytokine data was available for 15 participants. Five participants had sufficient vitamin D status at baseline (5 out of 19, 26%), and twelve and two participants presented insufficient (63%) and deficient (11%) status, respectively. At both the winter and spring timepoints, only one participant out of 16 had sufficient vitamin D status (6%), whereas eleven and four presented with insufficient (69%) and deficient (25%) status, respectively. The mean weight loss of participants was calculated to be 4.1±2.4 kg, most of which occurred between the fall and winter. The authors concluded that they could not find a relationship between vitamin D status and risk of injury, illness, or infection, however they have identified a potential for vitamin D deficiency or insufficiency in wrestlers. This study indicates a possible deficiency of vitamin D in this population, prompting further research and monitoring nutritional intake in this population. Furthermore, analyzing nutrient intake as a whole may expose other deficiencies for athletes to be aware of.

Daneshvar et al., 2013

The purpose of this study was to examine if young adult wrestlers are at higher risk of nutrient deficiencies than athletes of other sports by evaluating dietary habits and nutritional status. The subject pool was composed of 28 male wrestlers, aged 17-25 years, all being part of different wrestling clubs in Isfahan, Iran. Dietary status was assessed through a face-to-face structured food frequency questionnaire, broken up into five food groups. These groups were: mixed dishes, grains (breads, biscuits, cakes, and potatoes), fruits and vegetables, dairy products, and miscellaneous food (including fast food, and sweets). Intake of energy, carbohydrate, protein, and fat was gathered, along with certain vitamins (B1, B2, B3, B6 C, D, Folic Acid, and Biotin) and minerals (iron, calcium, magnesium, zinc, selenium, iodine, and manganese). The mean intakes for energy, carbohydrates, protein, and fats were all higher than the RDA (3162.35 kcals, 472.2 grams, 121.4 grams, and 103.2 grams, respectively). Intakes of most vitamins and minerals were higher than the RDA as well, except for Vitamin D (70.7% of RDA), biotin (34.9%), zinc (79%), and iodine (13.85%). The authors noted the importance of the Vitamin D and biotin deficiencies, as Vitamin D plays a role in repair, maintenance, and development of bones, and biotin takes part in tissue repair and maintenance as well as energy metabolism. This study highlights potential nutrient deficiencies in wrestlers and emphasizes the need for tracking nutrient intake, particularly leading up to the competition season when weight regulation activities take place.

Iguchi et al., 2020

The purpose of this study was to evaluate the most effective training plan for collegiate rowers. The subjects consisted of 15 collegiate male rowers, from the same university. The 2012-2013 rowing season was evaluated, broken up into 3 macrocycles: off-season, pre-season, and in-season (competition). The off season lasted 16 weeks and consisted of moderate to high volume and low intensity training. The pre-season was five weeks long, consisting of moderate volume and moderate to high intensity training. In-season was also 16 weeks long, with low-moderate volume, and high intensity training. The 2,000 m rowing ergometer time trial was used as the predictive time for performance and completed regularly. Because they are known to contribute to athletic performance, energy expenditure/intake and body mass were recorded throughout the 3 seasons. The results indicated a significant decrease in 2,000 m rowing ergometer time from 6:55 min in-season compared to 7:01 min in pre- and 7:04 min in off-season (p= $2.0\text{x}10^{-4}$). Additionally, carbohydrate and protein intake were highest in-season with mean intakes of 7.8 $g \cdot kg^{-1}$ and 1.7 $g \cdot kg^{-1}$, respectively, while fat intake was lowest during in-season (0.9 $g \cdot kg^{-1}$) (p=$1.0\text{x}10^{-3}$ – $6.6\text{x}10^{-4}$). The authors concluded that high carbohydrate and protein intake potentially lend to better training adaptations, leading to better performance. Furthermore, despite differences in training time and intensity, and significant changes in performance, body composition remained relatively stagnant throughout the 3 seasons. The main findings from this study suggest that higher nutritional requirements may be necessary during in-season for optimal performance, emphasizing the importance of monitoring dietary intakes of athletes during competition season.

Jagim et al., 2021

The purpose of this study was to assess the sports nutrition knowledge of NCAA Division III athletes, and evaluate relationships between knowledge, body weight goals, and body composition. The study consisted of 67 total Division III athletes, with 42 women, and 25 men. Air displacement plethysmography was used to examine body composition. To evaluate general and sports nutrition knowledge, participants completed the Abridged Sport Nutrition Knowledge Questionnaire (A-SNKQ). A questionnaire was created to examine perceived energy and macronutrient intake on a typical day, which was then compared to calculated energy and macronutrient recommendations given by the International Society of Sports Nutrition (ISSN). Participants were also asked to identify nutritional barriers, and their current body weight goals. The mean score on the

A-SKNQ was 47.9±11.3% which is classified as "poor". An inverse relationship was found between sports nutrition knowledge and body fat percentage and fat mass (r= -0.33, r= -0.268, respectively). All participants significantly underestimated their daily energy, carbohydrate, and fat requirements when compared to their calculated requirements using a "moderate" physical activity level. For the female group, every 1% increase in body fat, and 1 kg increase in fat mass meant participants were 1.2 times more likely to choose weight loss as their current body weight goal. No body composition measurements had a significant relationship with body weight goals in the male group. The authors note that participants' lack of knowledge regarding their individual requirements may indicate a poor perception of their actual intake. The authors conclude that Division III collegiate athletes lack sports nutrition knowledge and underestimate their energy and carbohydrate requirements. This study indicates the potential for poor nutrition knowledge and intake among athletes who do not have access to nutritional support and highlights the need for further research to better define the nutritional habits of athletes, and how that may relate to performance.

Silva et al., 2017

The purpose of this study was to evaluate the energy balance (EB) changes over one competitive season of high level athletes, and how the rate of change of body energy stores relates to the change in fat free mass elements (FFM). The subjects consisted of 80 athletes (54 male and 26 female) competing in basketball, handball, volleyball, swimming, and triathlons at national and international events. The study was broken up into two measurement periods: the first being the beginning of season, and the second the main competition season. Fat mass (FM) and fat free mass (FFM) were estimated using dual-energy x-ray absorptiometry (DXA) and, total body protein (TBPro) was calculated using a four-compartment model. Resting energy expenditure (REE) was estimated using indirect calorimetry, and total energy expenditure (TEE) was calculated using the doubly labeled water (DLW) method. Average energy intake (EI) was estimated using DXA and DLW in the first week of each measurement period. The mean EB for all athletes was -17.4 ± 72.7 $kcal \cdot d^{-1}$, whereas BW and FFM were shown to increase by 1.1% and 1.9% respectively, and FM decreased by 2.3%. Total body protein increased by 0.7 kg, attributed to adequate intake of protein even during negative energy balance. The authors conclude that there was a small, but statistically significant, negative energy balance observed, but the large discrepancy between sex and sport groups is important to note. It is important to monitor body composition and energy balance changes in athletes throughout a season, particularly in weight class sports, which this study did not include.

Zanders et al., 2021

The purpose of this study was to analyze energy balance and magnitude of change of daily caloric needs throughout the women's collegiate basketball season. The study consisted of 13 female collegiate basketball players, ages 18-23. For data collection, the season was split into five phases each about a month apart, and data was collected in each phase. Body composition was collected using Dual Energy X-ray Absorptiometry (DXA) only once at the beginning of the study. Indirect calorimetry was used to gather Resting Metabolic Rate (RMR) data. To gather activity energy expenditure, athletes were monitored with integrated heart rate and uniaxial accelerometer activity monitors for four consecutive days in each phase. The monitors were worn for the entire planned activity period. Athletes also completed four-day diet logs during monitoring to assess intake. Questionnaires were used to gather data on sleep and recovery patterns for these four days as well. The study found that athletes' restfulness increased throughout the season, and total daily energy expenditure decreased, while activity energy expenditure stayed constant. Energy balance did not significantly change throughout the season and was calculated to be negative for each phase. Daily caloric, carbohydrate, and fat intake was consistent throughout the season, while mean protein intake decreased from 97.7 $g \cdot d^{-1}$ to 84.7 $g \cdot d^{-1}$ by the end of the season (p=0.07). Additionally, carbohydrate and protein intakes were lower than recommended amounts. The authors concluded that appropriate energy balance is hard to attain, and maintain for student athletes, highlighting the need to monitor intake and expenditure of athletes during different parts of their season, particularly in weight class sports. Furthermore, carbohydrates and protein intake can influence performance in athletes, so while not examined in this article, performance and recovery could be impaired due to inadequate nutrition.

Jontony et al., 2020

The purpose of this study was to identify differences in dietary quality of various NCAA DI sports, as well as examine changes in body fat percentage (BF%) and skin carotenoids between competition season and off season. The study consisted of 129 athletes, competing in rowing, swimming, gymnastics, and wrestling. Dietary intake was assessed using a 30-day food frequency questionnaire, and Healthy Eating Index scores were calculated based on results. A biophotonic scanner was used to evaluate the skin carotenoids of the hand. Body composition was assessed using dual energy x-ray absorptiometry (DXA). Mean HEI score for all teams was 71.0 ±11.2; wrestling had the lowest mean score with 56.5 ±5.7. Total diet quality of wrestling was significantly lower than women's rowing ($p = 0.001$) and swimming ($p = 0.007$). Skin carotenoids were lower for all teams, excluding wrestling, when out of season, compared to in season. For women's teams, mean BF% was lower in season (22.7%) compared to out of season (24.7%). Conversely, men's teams had higher mean BF% in season (14.4%) compared to out of season (13.4%). The authors note that while the overall HEI scores are low, teams had higher individual scores for intake of protein foods, and fruit, with low scores for fatty acid and whole grain intake. Additionally, participants in this study did have access to athlete-specific fueling stations, and prepared meals, which is not available at many universities. The authors conclude that NCAA DI athletes exhibit suboptimal diet quality, particularly out of season, which could negatively affect sports performance and overall health. This study indicates potential weaknesses of nutrient intake among collegiate athletes, and highlights the need for further research, particularly for weight class sports such as wrestling, and at universities that lack athlete focused nutritional support. Furthermore, comparing performance measures with intake data may help establish recommendations for this population.

Physical Demands of Wrestling

<u>Ratamess et al., 2013</u>

The purpose of this study was to analyze changes in body composition, strength, anaerobic power, hydration status and endocrine values throughout a Division III collegiate wrestling season, and to compare measurements between starters and non-starters. The study consisted of 18 male wrestlers, from a top 20 ranked DIII wrestling team. Participants were split into starters (n=7), and non-starters (n=11). Blood samples were collected to analyze hematocrit, testosterone, and cortisol levels. Hydration status was evaluated using urine samples. Skinfold measurements of the pectoral, anterior thigh, and abdominal regions were used to assess body composition. A hand dynamometer was used to assess maximal isometric hand grip strength. A vertical jump and a Wingate test were used to evaluate anaerobic power. Measurements were taken four times: before the pre-season training period (T1), three days before the first competition of the season (T2), in the mid-season one day before a competition (T3), and one week before the National Championships (T4). Testosterone concentrations for the whole team were significantly reduced at T2, T3, and T4 compared to T1 ($p \leq 0.05$). For all wrestlers, body mass was significantly lower at T2, and T3 than T1 ($p \leq 0.05$), and T4 was higher than T3 ($p \leq 0.05$). Body fat percent (BF%) at T2 and T3 was significantly lower than T1 ($p \leq 0.05$). Fat mass was significantly lower at T2 and T3 than T1 ($p \leq 0.05$), and significantly increased at T4 ($p \leq 0.05$). For all participants, grip strength was significantly lower only at T2 ($p = 0.05$). Peak power and force calculated by the jump test was significantly lower in all wrestlers at T2, T3, and T4 ($p \leq 0.05$), but no differences were calculated when examining starters only. Peak power on the Wingate test was lower at T2 and T3 compared to T1, and higher at T4 than T2 for all wrestlers ($p \leq 0.05$), but no significant differences throughout the season were calculated for the starters only. The authors conclude that athletes who regularly make weight and compete respond to a competitive season differently than athletes who compete irregularly, and that wrestlers demonstrated an ability to maintain relative power throughout the season. This study highlights body composition, hormonal, and performance changes that may occur over a collegiate wrestling season. Evaluating nutrient intake and additional performance measures may add more detail for researchers to examine how these factors interact.

Ramirez-Velez et al., 2014

The purpose of this study was to examine the anthropometric characteristics and performance measures of elite male wrestlers. The study consisted of 21 male wrestlers, all with at least three years of elite competition experience. Height and weight were measured with a stadiometer and an electronic scale. A Lange skinfold caliper measured skinfold thickness at the biceps, triceps, subscapular, chest, abdomen, suprailiac, anterior thigh, and medial calf regions. These measurements were used to calculate the body fat and muscle mass percentage, and the absolute body fat and muscle mass in kg. An Astrand-Rhyming protocol was used to analyze maximal oxygen consumption ($\dot{V}O_{2max}$). Vertical jump (VJ), standing broad jump (SBJ) and a Wingate anaerobic test were used to evaluate anaerobic power. The mean body fat percentage of participants was 13.6±3.0%, and mean muscle mass percentage was 46.4±2.2%. The mean $\dot{V}O_{2max}$ was 45.9 ±6.6 $ml \cdot kg^{-1} \cdot min^{-1}$, mean anaerobic power calculated from the VJ and SBJ was 92.6±19.5 $kg \cdot s^{-1}$, and mean peak power of the Wingate test was 269.1 ± 41.9 $W \cdot kg^{-1}$. The authors conclude that these physiological measures will not necessarily predict success, however they can supply reference measures for similar studies. This study indicates that anaerobic and aerobic measures of performance are valuable to wrestlers, and adding strength measures, and quantitative nutrient intake data will help researchers examine interactions between body composition, performance, and intake.

Vardar et al., 2007

The purpose of this study was to evaluate relationships between anaerobic performance and fat free mass (FFM) and percent fat mass (%FM) of young elite male and female wrestlers. The study consisted of wrestlers (n=18) aged 15-19 years old, all competing at the national or international level. Participants completed a questionnaire to gather data on age, wrestling history, and training habits. Bioelectrical impedance analysis was used to assess body fat, and a 30 second Wingate test was used to measure anaerobic capacity. The mean peak power of the male group was 8.5 $W \cdot kg^{-1}$. Mean anaerobic power and minimum power were both positively correlated with FFM in males and females (r= 0.73, and r=0.71, respectively). For the whole group, there was a strong relationship between peak power and FFM in males (r= 0.81), minimum power and FFM in males and females (r=0.83, r=0.71, respectively), and mean power and FFM in males and females (r= 0.90, r= 0.73, respectively). No relationship was found between power and %FM. The authors conclude that FFM should be the focus of training to improve anaerobic power, rather than %FM. This study indicates relationships between body composition and anaerobic capacity. These findings could be expanded upon by additionally evaluating aerobic capacity and strength, as well as comparing body composition with quantitative nutrient intake data.

Pappassotiriou et al., 2018

The purpose of this study was to present biochemical measures during the preseason and examine the changes in Greco-Roman and Freestyle wrestlers. A total of 20 male wrestlers participated in the study, including Greco-Roman wrestlers (n=11) and Freestyle wrestlers (n=9), with an age range of 14-31 years old. A digital beam scale was used to measure height and weight. A skinfold caliper was used at four sites (biceps, triceps, subscapular, suprailiac), and these measurements were used to calculate body fat percentage. An armband accelerometer was used to evaluate exercise intensity. Blood was collected by a middle finger prick to analyze blood glucose and lactate concentration immediately before and after a regular training session. A morning urine sample was collected from 19 of the 20 participants in order to estimate creatine metabolism and renal clearance. Calculated body mass index-for-age z-scores (BAZ) classified nine participants as normal weight, five as overweight, and six as obese. Significantly higher lactate concentrations were measured at the end of exercise compared to immediately before training. Additionally, circulating glucose was significantly higher after training than before. Elevated creatinine concentration was found in thirteen participants, while six presented with lower creatinine concentration. Twelve of the participants presented with a leakage of albumin, with a mean of 30 $mg \cdot L^{-1}$. For four of these participants, the albumin to creatinine ratio (ACR) was calculated to be ≥3.39, classifying them in the abnormal range. The authors conclude that wrestling training results in lactate concentrations increasing above the lactate threshold, further promoting gluconeogenesis, and the increase of resting lactate indicates the need for monitoring to gauge fatigue and overtraining. The study highlights short term metabolic changes resulting from wrestling training and supports the need for further research to evaluate how this may influence performance. Additionally, determining nutritional intake of wrestlers may provide insight on methods to reduce metabolic changes that result in fatigue and overtraining.

Gierczuk et al., 2012

The purpose of this study was to analyze the anaerobic power and capacity of arms and legs of young Greco-Roman wrestlers across three training years. The subjects consisted of male wrestlers (n = 12), 16 years old at the beginning of the study, and 19 at the conclusion. Standard medical scales were used to record body mass and height, and body fat was estimated by bioelectrical impedance analysis (BIA). Anaerobic power was analyzed using arm cranking and leg cycling 30s Wingate tests. The study was done in identical conditions with the same participants four times, each separated by one year. The body mass, fat free mass, and height of participants all increased over the study period. The highest peak and mean power of both upper and lower limbs was recorded in 19 year old wrestlers. The upper limb power was similar between the athletes at 17 and 18 years old (mean power of 7.0±0.4 $W \cdot kg^{-1}$, 7.1±0.5 $W \cdot kg^{-1}$ respectively). The leg power of the participants at 18 years old (7.7±0.3 $W \cdot kg^{-1}$) was lower than at 17 years old (8.6±0.3 $W \cdot kg^{-1}$). The authors conclude that wrestling training does not interfere with the proper anthropometric growth pattern, but that inappropriate training loads may interrupt short term power outputs. This study provides some performance values to use as comparison among a similar subject pool. Furthermore, it highlights the need for additional performance variables to be studied in order to collect more comprehensive data. Additionally, examining relationships between nutrient intake and performance measures could provide valuable information on wrestling patterns over years in the sport.

McGuigan et al., 2006

The purpose of this study was to evaluate for relationships of isometric max strength, rate of force development (RFD), and one repetition maximum (1RM) strength with other factors that can contribute to performance in collegiate wrestlers. The study consisted of male wrestlers (n = 8) from the same NCAA Division III wrestling team. Data collection was conducted during the off season; therefore, participants were not managing bodyweight. Isometric max strength was evaluated with the isometric mid-thigh pull exercise. Dynamic strength was tested by a 1RM for the back squat, bench press, and power clean lifts. Explosive muscle power was analyzed by a vertical jump test. Both the participants and the coaches were asked to issue rankings on a 0-100 scale. Participants ranked themselves, and the coaches ranked each participant. Rankings were based on actual performance rather than work ethic or athletic potential. The study found that correlations between isometric max strength and power clean 1RM (r= 0.97) and squat 1RM (r= 0.96) was nearly perfect. There was a strong correlation between RFD and the coaches ranking (r= 0.62). No other significant correlations were found. The authors noted that the vertical jump values for this study population were lower than elite athletes in previous studies. Conversely, the RFD values of this population were similar or higher than other elite wrestlers, supporting the idea that RFD may not be an important performance indicator for wrestlers. The authors conclude that the isometric mid-thigh pull test does correlate well with 1RM, particularly in back squat and power clean. Furthermore, the absence of correlations between other performance measures may be due to wrestling's unique metabolic demands. This study indicates that strength measures alone are not enough to predict performance in wrestlers.

<u>Hubner-Wozniak et al., 2019</u>

The purpose of this study was to evaluate the aerobic fitness level of female wrestlers, as well as analyze whether there are differences in physiological responses to graded exercise between sex. The study consisted of elite wrestlers from the Polish national team (n=20; males, n=10, females, n=10). Maximal oxygen consumption ($\dot{V}O_2$max) and anaerobic threshold of participants was measured by a graded exercise test on a treadmill. Additionally, blood was taken from the fingertip at the end of each workload, and three, five, and seven minutes into the recovery period to calculate peak lactate accumulation. The mean $\dot{V}O_2$max of the male group was 59.8±8.6 ml·min^{-1}·kg^{-1}, whereas the mean for the female group was 49.7±2.7 ml·min^{-1}·kg^{-1}. Peak lactate accumulation was calculated as 14.1±2.6 mmol·L^{-1} for males and 10.5±2.2 mmol·L^{1} for females. At anaerobic threshold, mean oxygen uptake of the male group was 43.0±8.1 ml·min^{-1}·kg^{-1}which was calculated to be 71.7±11.8 %$\dot{V}O_2$max. For the female group mean oxygen uptake at anaerobic threshold was 40.3±7.0 ml·min^{-1}·kg^{-1}, which was 81.7±9.2 %$\dot{V}O_2$max. The authors found that male wrestlers had greater average $\dot{V}O_2$max; however, the female populations' higher oxygen uptake at anaerobic threshold may have compensated for lower $\dot{V}O_2max$. This study gives markers for oxygen consumption of elite wrestlers, and highlights the need to test other performance factors, such as strength. Additionally, relating these factors to nutrient intake could provide greater depth of data.

Callan et al., 2000

The purpose of this study was to evaluate the physiological attributes of elite freestyle wrestlers preparing for the World Championships. The study consisted of eight wrestlers on the US World Team. The participants had won 4 gold medals, and 5 silver or bronze medals at previous World and Olympic championships. Body composition data was collected by skinfold measurements of 7 sites: chest, midaxillary, triceps, subscapular, umbilicus, suprailium, and thigh. A vertical jump protocol assessed lower body muscular power, and upper body muscular power was assessed by a rope climb. Hamstring and lower back flexibility was collected from the sit-and-reach protocol. Data on anaerobic capacity, as well as upper body power and fatigue over five 30-second stages was gathered from an upper-body Wingate test. Maximal oxygen consumption ($\dot{V}O_2max$) was gathered from the standard US Olympic Committee (USOC) treadmill or cycling protocols. Mean body fat percentage was 7.6±3.4%. The mean vertical jump was 60±10 cm, while mean time for the rope climb was 9.3 ± 4.4 seconds. The average reach for flexibility was 3.8±5.8 cm past the toes. Mean peak power for each stage of the upper-body Wingate test was calculated as 6.3, 4.7, 3.8, 3.5, and 3.5 $W \cdot kg\ BW^{-1}$ respectively. Average $\dot{V}O_2max$ for the treadmill test was 54.6±2.0 $ml \cdot kg^{-1} \cdot min^{-1}$, and for the cycle test was 41.2±6.1 $ml \cdot kg^{-1} \cdot min^{-1}$. In regard to body fat, the authors noted that athletes were an average of 5.5 kg heavier than their competitive wrestling weights, and they had relatively low fat stores to draw on in order to make weight. The authors conclude that these physiological factors may not predict success, but all contribute to wrestling performance. Additionally, the data reported could provide some goals for developing athletes. This study highlights the variance of physiological factors that are involved in wrestling performance and indicates the need for future research to collect comprehensive data.

Demirkan et al., 2015

The purpose of this study was to analyze physical and physiological factors of success in elite and amateur wrestlers. There were 126 young wrestlers (age 15-17 years) that took part in this study. All the participants were following the same dietary plan as part of a national training camp during this study. Participants were split up into six groups based on weight (light, middle, and heavy), and competitive level (elite or amateur). Skinfold thickness was measured at the subscapular, triceps, and abdominal sites to gather body composition data. Two Wingate tests were performed, on the arms and legs, to calculate anaerobic capacity. Sprint running speed of wrestlers was analyzed by dual-beam electronic timing gates. Hand grip, back strength, and leg strength was measured using a hand grip dynamometer, back muscle, and leg muscle dynamometer, respectively. A shuttle run multistage test was used to determine aerobic endurance. Flexibility was analyzed by a sit-and-reach test and agility was evaluated by an Illinois test. For the middle weight group, elite athletes had statistically higher leg peak power, leg peak power, leg average power, and relative leg average power than amateur athletes (6.5-13%). Relative leg average power was also higher in heavy weight elite (HWE) wrestlers than the heavy weight amateur (HWA) group (9.8%). Middle weight elite

(MWE) and HWE wrestlers also had higher maximal oxygen consumption ($\dot{V}O_2max$) (12.5% and 11.4%) than middle weight amateur (MWA), and HWA wrestlers. By using a binary logistic regression analysis, the authors found that 5 of the 29 variables evaluated (training experience, anaerobic average power calculated by Wingate power, and anaerobic average power ($W \cdot kg^{-1}$), flexibility, and $\dot{V}O_2max$) had an 84.8% prediction accuracy of classifying athletes in the correct group. This suggests that training experience, anaerobic capacity, flexibility, and maximal oxygen uptake can be important factors in wrestling success; however, other factors such as wrestling skill and psychological factors cannot be ignored. This study highlights the multiple physiological factors that influence wrestling performance, indicating the need for comprehensive data in this population in future research.

Cieśliński et al., 2020

The purpose of this study was to define and rank the factors of wrestling success for any weight class and style. The study consisted of a total of 168 Polish wrestlers, with a mean age of 20.42± 2.50 years old, and mean wrestling experience of 7.76± 2.60 years. Participants were divided into a successful group (n= 85), defined as individuals who won medals (top four spots) in Polish Junior and Senior Championships, and two international competitions, and a less successful group (n=83), being individuals receiving 5^{th}-8^{th} place finishes in those competitions. Anthropometric measurements of body mass, standing height, length of upper and lower limbs, circumferences of arm, forearm, thigh and calf, width of shoulders and pelvis, and skinfold thickness were taken. Body composition was evaluated using Bioelectrical Impedance Analysis (BIA).

Standing broad jump was used to assess dynamic strength, while pull-ups and hanging leg raises assessed strength endurance. A zigzag test was used to assess agility, and wrestling specific technical skills, fitness, and special endurance were assessed. Response time was measured using an RT test, and Batak Lite test. A 30-s Wingate was used to assess upper and lower limb anaerobic capacity. The variables of peak power of upper limbs, strength endurance, response time, special endurance, wrestling-specific fitness, and technical wrestling skills were reported to be the most accurate in classifying successful and less successful participants, with order of importance listed respectively. The authors note that when comparing their results with previous studies, the best predictive performance factors are those involving technical skills, basic conditioning abilities, and anaerobic capacity. The authors conclude that these factors may be used to monitor the effectiveness of training programs for wrestlers. This study indicates certain performance factors important to wrestling success. Additionally comparing nutrient intake data may provide researchers and athletes more information to improve their performance.

Nutritional Concerns of Weight Cutting

Kondo et al., 2018

The purpose of this study was to assess the energy deficit required for rapid weight loss (RWL) in wrestlers and to evaluate whether the four-compartment (4C) model, 3-compartment (3C) model, air displacement plethysmography (ADP), dual energy x-ray absorptiometry (DXA), stable isotope dilution (SID), and bioelectrical impedance analysis (BIA) can accurately measure energy balance from body composition changes. The study consisted of eight male collegiate wrestlers competing at universities in the Kanto area, Japan. The subjects were tasked with losing six percent of their body weight in a three day period, with methods for weight loss being chosen by each subject. Total body water was calculated using stable isotope dilution, and the doubly labeled water method was used to calculate total energy expenditure (TEE). Energy intake (EI) was estimated using data from diet records, and energy deficit was calculated by subtracting TEE from EI. Energy deficit was also estimated using the 4C, 3C models, ADP, DXA, BIA, and SID methods. Body mass (BM) decreased by 4.7 kg, with TBW making up 71% of that loss. Energy deficit during the RWL period was calculated as 7080 ± 1525 kilocalories (kcal), and energy density was 1507 ± 279 $kcal \cdot kg\Delta BM^{-1}$. Additionally, the authors found that the energy density calculated by the 4C, 3C, DXA, and SID methods were not significantly different than the EI – TEE calculation, however the ADP, and BIA calculations were significantly greater. The same was true for calculations of FM loss. The authors conclude that extreme energy restriction of 7400-7700 $kcal \cdot kg\Delta BM^{-1}$ for RWL appears to be harmless. Additionally, the 4C model can be used accurately to calculate energy deficit, and energy density could be calculated using the 3C model, DXA, and SID, but ADP, and BIA should not be used. This study emphasizes proper methods to use for energy density calculations, as well as highlighting the need to study safe methods to approach RWL. While this study supports methods to safely incorporate rapid weight loss through dietary intake, examining how this impacts performance will be beneficial to the sport of wrestling.

Gorrell et al., 2019

The purpose of this study was to evaluate differences in binge eating, extreme weight control behaviors (EWCBs) and exercise behavior between competitive and non-competitive collegiate male athletes, as well as analyze the differences in eating and exercise behavior between sports. The study consisted of male athletes (n = 612) 18-26 years old, all attending one of the top ten ranked National College Athletics Association (NCAA) schools, of which (n = 429) participants were competitive athletes. Participants completed the Eating Disorder Examination Questionnaire (EDE-Q) to gather data on driven exercise behaviors, binge eating, or EWCBs. Baseball, Cycling, and Wrestling scored the highest global EDE-Q scores, respectively. Wrestling had the second highest *Restraint* subscale scores, with 24% reporting clinical restraint. A total of 57% of the wrestlers reported driven exercise to influence weight or shape, and this was significantly greater than all other sports. The authors suggest that their findings support earlier studies stating that wrestling is a higher risk sport for eating pathology. Overall, baseball players, cyclists, wrestlers, and rowers reported significantly higher EDE-Q global scores than other sports. When accounting for reasons for exercise and other reported EWCBs, the authors conclude that wrestlers, rowers, and cyclists (each of these being weight class or weight sensitive sports) are the sports with the greatest risk of unhealthy eating and exercise behaviors. This study emphasizes the health-risk-related behaviors wrestlers, and other athletes engage in, and highlights the need for more in depth nutrient analysis. Furthermore, analyzing performance measures could provide more insight on how these behaviors influence the sport, particularly when compared across seasons.

Kondo et al., 2021

The purpose of this study was to analyze the effect of a high carbohydrate meal on muscle glycogen (MGly) concentration after rapid weight loss (RWL). The study consisted of ten male collegiate wrestlers from two Japanese college teams. After baseline measurements were taken, participants were tasked with losing 6% of their body mass in a 53 hour period. After that period, measurements were taken (R0), and participants were given three meals containing a total of 7.1g of carbohydrate per kg of body weight in a five hour period. Body composition was assessed with dual x-ray absorptiometry (DXA), and magnetic resonance imaging was used to assess the cross sectional area (CSA) of the right femoral region. Carbon magnetic resonance spectroscopy was used to gather MGly concentrations of the right thigh. Measurements were taken 2 hours (R2), 4 hours (R4) and 13 hours (R13) after the first prescribed meal. Participants were instructed to weigh all food, beverages, and supplements consumed three days prior to the baseline measurements, and during the RWL period to analyze food and fluid intake. During the RWL period, daily energy intake was decreased by 67.6±11.2%. After the first recovery meal, body mass increased by 2.2±0.5 kg, and by 3.3±0.5 kg after the third recovery meal, but body mass at R13 was 1.7±0.6 kg lower than BL. Muscle CSA decreased by 5.9±1.3% after RWL and increased by 3.8±2.0% during the recovery period. After RWL, MGly concentration was 6.5±10.0% lower than at BL and had not recovered at R13. The authors concluded that a high carbohydrate meal of $7.1g\cdot kg^{-1}$ of body mass was inadequate to recover the MGly lost during a 6% RWL. This study indicates the high nutrient needs of athletes after RWL, and the need for further research to optimize the recovery process. Additionally, measuring performance values as well as nutrient intake could provide better depth of information on how these practices are affecting wrestlers.

Close et al. 2019

This study is a literature review focusing on the use of nutrition to prevent injuries, increase repair, and the alteration of energy needs during an injured state. The authors note that there is a lack of research directly related to preventing and treating injuries, with most studies revolving around laboratory induced muscle soreness. While this is considered a limitation, the available data can still be useful to guide practice. With that in mind, there is evidence that athletes who take part in whole body resistance training may need more than the 20 grams of protein per meal that is often recommended. Some recent studies suggest about 40 grams per meal is the optimal amount, with equal division throughout the day being important as well. Additionally, 2.3 grams$\cdot$kg^{-1} of protein may reduce the loss of lean body mass (LBM) in periods of decreased energy intake. Research indicates that sustaining energy availability at 45 kcals $\cdot$ kg LBM^{-1} $\cdot$ day^{-1} is important to optimize athlete bone health, and potentially will help prevent bone injuries. In a study of military recruits during basic training, stress fractures were associated with dietary deficiencies of Vitamin D, calcium, and carbohydrate intake. To reduce risk, 800 International Units (IU's) of Vitamin D, and 2,000 mg of calcium supplementation daily is recommended. Furthermore, a pre-exercise meal containing about 1300 mg of calcium, or a 1000 mg supplement of calcium helps prevent disruptions in calcium homeostasis; this supplementation is only necessary for endurance athletes engaging in either prolonged, or multiple workouts, and potentially weight class athletes undergoing dehydration in order to make weight. The authors conclude that it is vital to avoid long term low energy availability to help prevent injuries. For weight sensitive sports such as wrestling, it is likely ideal to cycle intake within the season to reach competition weight, but also have adequate energy availability when separated from competition.

Castor-Praga et al., 2021

The purpose of this study was to analyze methods of rapid weight loss (RWL), along with performance perception and psychophysiological variables, correlated with the magnitude of weight loss in wrestling and taekwondo (tkd) athletes. The study consisted of 160 total athletes (n=48 wrestlers, n=112 tkd), ranging from 7-24 years old. All participants had at least one year of competitive experience in their respective sport. To gather data on RWL strategies, consequences of mood, perception of performance, and the social environment encouraging RWL, a four section questionnaire was created. A total of 96% (n=153) of participants reported engaging in RWL strategies. Of these, the relative weight lost was calculated for 148, and this sample was split into two groups: 57.4% lost greater than 5% of their body mass (BM), and 42.6% lost less than 5% of BM. Wrestling athletes were found to lose more weight on average than tkd athletes, and wrestlers started practicing RWL younger than tkd athletes. A total of 82.03% of participants reported using gradual dieting, 83.59% reported increasing exercise, and 85.7% trained in plastic or thick clothes to lose weight. Females had a higher prevalence of using fasting, laxatives, and omitting food than males. When comparing wrestling and tkd, no significant differences were found for methods of RWL. For the group losing more than 5% of their BM, the most severe physiological symptoms were lack of tears and urine. Additionally, this group showed greater severity of symptoms than the group losing less than 5% BM. A higher intensity of symptoms associated with urine was reported for athletes of wrestling compared to tkd. The negative mood states reported most commonly were fatigue and confusion, and athletes training with plastic or thick clothes reported a higher intensity of fatigue. Of the athletes engaging in RWL, 76.1% perceived a negative influence on performance, whereas 23.8% perceived no influence. Comparing sports, 25.18% of wrestlers perceived a decline in performance, while 8.88% perceived no change; 50.37% of tkd athletes perceived a decrease in performance and 15.55% perceived no change. The authors conclude that the negative symptoms associated with RWL found in their study support the need to implement changes to reduce these practices. Furthermore, future studies should incorporate longitudinal and quantitative measures. Examining quantitative measurements of performance may give more detail as to the effects of these practices and help develop more specific nutritional recommendations for weight loss strategies.

<u>Pallares et al., 2016</u>

The purpose of this study was to analyze whether dehydration of Olympic combat sport athletes lowers neuromuscular performance and examine relationships between body mass gained post weigh-in and performance results in a competition. The study consisted of 124 male and 39 female athletes, competing in wrestling (n=76), taekwondo (n=62), and boxing (n=25). Participants were assessed for body mass, hydration and neuromuscular performance two separate times: within one hour before the official weigh-in of their National Championship tournament (PRE), and within one hour before the first match of the tournament (POST). To assess mean propulsive velocity (MPV), a bench press graded submaximal loading test was performed. Mechanical power was assessed using a counter movement jump (CMJ) test. A dynamometer was used to evaluate grip strength of both hands. Urine samples were collected to evaluate hydration status. At the PRE assessment, participants were split into three groups based on urine osmolality (U_{OSM}). Participants with U_{OSM} from 250 to 700 mOsm·kg H_2O^{-1} were euhydrated (EUH), 701 to 1,080 mOsm·kg H_2O^{-1} was classified as hypohydrated (HYP), and 1,081 to 1,500 mOsm·kg H_2O^{-1} was classified as severely hypohydrated (S-HYP). Between PRE and POST trials, the HYP group recovered 1.3% of body mass, and the S-HYP recovered 3.1% body mass. The S-HYP group recorded higher increases in MPV than the HYP and EUH group, and significantly higher CMJ increase than the EUH group ($p<0.001$). Participants who earned a top four finish in their weight class were classified as the elite group, and all others were grouped as non-elite. The elite group had a significantly higher proportion of S-HYP athletes (47% compared to 26%, $p=0.023$), and 69% of all the hypohydrated participants earned a medal. The authors noted that the increase in muscle power seen in the S-HYP group indicates that dehydration does lower neuromuscular function, but this can be at least partially reversed with rehydration. Additionally, U_{OSM} at the POST trial was not different between the elite and non-elite groups. The authors conclude that dehydration prior to weigh-in is highly prevalent among combat sport athletes and that most successful athletes undergo dehydration. Evaluating nutrient intake could additionally inform researchers about athletes' weight cut habits and prevent the need for severe dehydration protocols. Examining nutritional intake along with performance measures could help establish optimized weight cut plans for weight-class sports.

Ranisavljev et al., 2022

The purpose of this study was to identify the most common methods of rapid weight loss (RWL), and sources of influence among elite wrestlers, as well as analyze for any differences in methods among sexes. The study consisted of (n = 145) subjects from 16 different countries, all competing at the World Wrestling Championships. A validated, standardized RWL questionnaire was used to assess RWL methods. The questionnaire was composed of 21 items regarding personal information, competitive level, nutrition status, and RWL history and behaviors. A total of 82.5% (120) of the participants reported cutting weight prior to competition, with most beginning about nine days before the start of competition. Mean total amount of weight lost for each cut was 3.9 kg for men, and 3 kg for women. The method used most often to achieve RWL was gradual dieting (85.4% of males, 79.5% of females) followed by increased exercise (79% of males, 66.6% of females) and using a sauna (78.7% of males, 66.6% of females). The authors conclude that the prevalence and techniques used for RWL are cause for concern, and that athletes health needs to be prioritized over success. This study highlights the importance of evaluating nutritional status of wrestlers. Furthermore, evaluating this data alongside performance measures may give a better indication of how these techniques are affecting athletes.

CHAPTER III: Methods

Experimental Design:

This study was a cross-sectional study analyzing the nutrient intake, body composition, and performance values, including strength, anaerobic, and aerobic measures of collegiate wrestlers. Two trials were conducted during the wrestlers' pre-season (late September- early October) within a 7-day time period. Nutrient intake was collected from 3-day food diaries completed by each subject prior to each trial. Body composition data was gathered from skinfold thickness. An isokinetic dynamometer was used to evaluate hamstring and quadricep muscle strength. Aerobic and anaerobic capacity were tested on a stationary cycle ergometer, and lactate concentration was collected via capillary blood of the fingers and analyzed by a lactate analyzer. Additional data about each participant's medical history and current training habits was collected from a health status questionnaire.

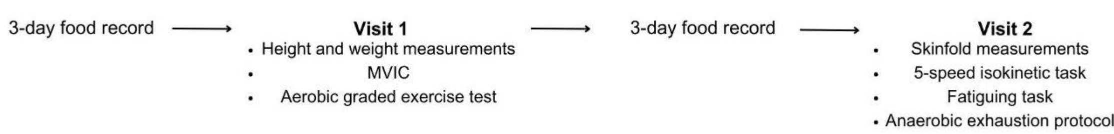


Figure 1. Study Design. MVIC, maximal voluntary isometric contraction

Participants:

A power analysis conducted with G*POWER 3.1 (Universität Kiel, Germany) for correlation analyses determined that 7 participants were needed in the present study for a correlation of 0.87, power of 0.80, and $\alpha = 0.05$.[34] Division I collegiate wrestlers (n=11) from a top fifteen team participated in this study (age = 21.3 ± 1.7 years, height = 174.9 ±

8.5 cm, weight = 82.1 ± 18.2 kg, wrestling experience = 14.9 ± 2.5 years). Participants were at the end of their pre-season training cycle, which has a larger focus on resistance training and aerobic exercise, with a training schedule of 6 days per week for approximately 2 hours per day. Participants were grouped into starters, defined as athletes who made weight for greater than 50% of scheduled competitions or at the Big 12 Conference Championships during the 2021-2022 season, and non-starters. All participants signed a written informed consent and completed a physical activity readiness questionnaire prior to data collection. This study was approved by the university Institutional Review Board (approval #2209012-EXP, approval date September 30, 2022).

Protocol:

Health status

Prior to the first trial, participants received a health status questionnaire, physical activity readiness questionnaire (PAR-Q), and 3-day food diary. The health status questionnaire gathered information on their health history, wrestling history, and information about current eating and training habits. The PAR-Q+[35] assessed ability to safely exercise. Height and weight were collected using a standing stadiometer, and digital scale (Seca gmbh & Co.kg Hamburg, Germany), respectively. Body composition was gathered using skinfold measurements taken with a Lange caliper (Model 68902, Cambridge Scientific Industries, Inc, Cambridge, MD) on the right side of the body, utilizing male 7-site skinfolds of the chest, midaxillary, triceps, subscapular, abdomen, suprailiac, and thigh. Each skinfold measurement was taken twice at each site with the average value recorded. Recorded measurements were used to calculate body density[36] and estimate fat mass (FM) (kg), FFM (kg), and BF%.[37] Fat-free mass (FFM) estimates were then used to estimate resting metabolic rate (kcals) using the Cunningham Equation.[38]

$$Resting\ metabolic\ rate = 500 + 22(FFM)$$

Nutrient Intake

A 3-day food record collected information on nutrient intake prior to each test visit. Participants were asked to record everything consumed on the three days leading up to each test visit. The research team, which included a Registered Dietitian, instructed participants on the proper way to complete the food record and reviewed the record with participants for accuracy upon collection. Data was entered into the PeopleOneHealth Food Tracker[39] and Cronometer[40] to analyze macronutrient and micronutrient composition. General nutrition intake results were discussed with participants after evaluation.

Strength tests

Isometric torque of participants' right leg was measured using a Biodex System 4 Quick-Set isokinetic dynamometer (Biodex Medical Systems, Inc., Shirley, NY). Participants were seated with pelvis, trunk, and contralateral thigh restrained. The lateral condyle of the femur was aligned with the axis of rotation of the leg extension device. During the first visit, maximum voluntary isometric contractions (MVIC) of the hamstring and quadriceps was taken. Isometric tests were performed with a flexion angle of 60º below the horizontal plane. Each participant completed two warmup leg extension and leg flexion muscle actions at approximately 50% and 75% of perceived effort and one practice attempt of leg extension and flexion MVICs. Each participant then completed two, 4-second leg extension and flexion MVICs in which participants were instructed to push or pull against the lever arm as hard as possible for extension and flexion, respectively. Peak torque was then recorded.

During the second visit, participants were seated on the Biodex identically to the first visit and performed maximal isokinetic tests. The range of motion was set from 180° to 90°. Three repetitions of maximal voluntary isokinetic muscle actions at 60, 120 180, 240 and $300°\cdot s^{-1}$, with 1-min rest between each angular velocity was performed. Participants were instructed to extend and flex their leg as hard and quickly as possible. Peak torque was recorded for each maximal contraction. For a leg muscle fatiguing task, isokinetic mode of the dynamometer was set at a velocity of $180°\cdot s^{-1}$ and the range of motion was set from 180° to 90°. Participants performed 50 maximal effort leg extension and leg flexion contractions with full range of motion. Peak torque for each contraction was recorded. Fatigue index was calculated by the following equation:[41]

$$\frac{initial\ torque - final\ torque}{initial\ torque} \cdot 100$$

Aerobic capacity

During the first visit, participants completed a graded exercise test on an electronically braked, calibrated cycle ergometer, to exhaustion. The seat was adjusted so that each participants' legs were nearly fully extended on each revolution, and toe clips were used to maintain pedal contact throughout the test. Throughout the test, blood lactate was collected via finger puncture and analyzed using an on-site lactate analyzer (LactatePlus, Sports Resource Group, Inc. Edina, MN). Finger punctures were taken every minute during the duration of the test. The fingertip was cleaned with an alcohol wipe and then pricked with a lancet. After wiping the finger with an alcohol wipe, a droplet of blood was placed on the analyzer to be measured immediately. The testing protocol began at 100 W and increased every minute by 25 W until participants reached volitional exhaustion, defined by a pedal cadence below 70 RPMs, or when participants reached a heart rate of 95% of age predicted heart rate max (208 – 0.7(age)), or $\geq$ 8.0 $mmol \cdot L^{-1}$.[42] Heart rate and lactate levels were recorded every minute. Participants were asked every two minutes to rank their rate of perceived exhaustion (RPE) on a 6-20 scale. Additionally, each participants maximal power (W_{max}) was recorded as the maximum power output measured during the final stage of the protocol.[43]

Anaerobic capacity

During the second visit, participants performed a five-minute warmup at 100 W, followed by five minutes of rest. The test effort was then incremented with the first 15 seconds being at 80 % W_{max}, the next 15 seconds being 95% W_{max}, then increasing to 110% W_{max} until volitional exhaustion was reached. Participants were instructed to pedal at a self-selected, constant pace. When participant's pace dropped by 20 RPMs, volitional exhaustion was reached, and participants were instructed to stop pedaling. The time to exhaustion (TTE, s) and total work done (TWD, kJ) were the recorded measures for each participant.[44] To analyze lactate concentration, finger puncture was taken before the test, immediately post-test, and five minutes post-test. The fingertip was cleaned with an alcohol wipe and then pricked with a lancet. A droplet of blood will be placed on the LactatePlus analyzer to be measured immediately.

Statistical Analysis

Means and standard deviations (SD) for body composition, performance measurements, and macronutrient and micronutrient intakes, were calculated in a spreadsheet software program (Microsoft Excel 2022, version 2208). A Pearson product moment correlation analysis was performed among macronutrient and micronutrient intakes from the second dietary record, body composition variables, W_{max}, TWD, TTE, and peak torque. For significant collinear relationships among dietary intakes, body composition, and performance measurements, first-order partial correlations (r_{xyz}) were calculated to partial out collinear influences. Reliability statistics were performed for the two dietary records. All statistical analyses were performed using IBM SPSS Statistics for Macintosh, Version 28 (IBM Corp., Chicago, IL, USA.). Statistically significant data is defined as all correlations and comparisons with an alpha of $p \leq 0.05$.

CHAPTER IV: RESULTS

Table 1 reports means ± SD for the body composition variables (height, weight, BMI, FFM, FM, eRMR, and eTEE). Table 2 reports the individual body composition measurements for each participant.

Table 1. Means (± standard deviations, SD) for body composition variables for n = 11 male collegiate wrestlers.

Body Composition Measurements	Mean ± SD
Height (cm)	174.9 ± 8.5
Body Mass (kg)	82.1 ± 18.7
Body Mass Index	26.5 ± 3.4
Fat-Free Mass (FFM) (kg)	73.9 ± 11.9
Fat Mass (FM)	8.1 ± 7.6
Estimated Resting Metabolic Rate (eRMR)	2127 ± 262
Estimated Total Energy Expenditure (eTEE)	3828 ± 471

Table 2. Individual body composition measurements for n = 11 male collegiate wrestlers.

Participant	**Height (cm)**	**Weight (kg)**	**Body Mass Index**	**Fat-free Mass (kg)**	**Fat Mass (kg)**	**Estimated Resting Metabolic Rate (kcal)**	**Estimated Total Energy Expenditure (kcal)**
1	167.0	69.8	25.0	66.6	3.2	1966	3538
2	181.5	96.5	29.3	87.0	9.5	2414	4345
3	180.5	103.8	31.9	86.8	17.0	2409	4336
4	171.5	66.5	22.6	62.0	4.6	1863	3353
5	164.0	65.4	24.3	61.6	3.8	1856	3341
6	170.0	68.0	23.5	64.0	4.0	1908	3435
7	168.0	64.4	22.8	61.7	2.7	1857	3343
8	175.3	78.0	25.4	74.0	4.0	2128	3831
9	173.0	82.4	27.5	74.1	8.3	2129	3833
10	179.0	86.0	26.8	80.7	5.3	2276	4096
11	194.0	122.0	32.4	94.8	27.2	2586	465

Table 3 reports means ± SD for energy, macronutrient, and micronutrient intakes for both records. Mean intake of four micronutrients (vitamin A, vitamin E, Folate, and Potassium) were below the Recommended Dietary Allowance (RDA) on at least one of two food records. Intraclass correlation coefficients (ICCs), standard error of the measurement (SEM), coefficients of variation (CVs), and minimum detectable changes (MDCs) between means of dietary intakes of the two separate 3-day dietary records are reported in Table 3. There were no significant differences between the mean values from Record 1 and Record 2 ($p = 0.110 – 0.793$). For energy and macronutrients, ICCs and CVs ranged from 0.668 – 0.871 and 19.45% - 27.45%, respectively. For micronutrients, ICCs and CVs ranged from -0.006 – 0.998 and 10.86% - 102.39%, respectively (Table 3).

Table 3. Means (± standard deviations, SD), intraclass correlation coefficients (ICCs), standard error of measurement (SEM), coefficients of variation (CVs), and minimum detectable changes (MDCs) for dietary intakes averaged over three days for n=11 male collegiate wrestlers. Record 1 and 2 were separated by 4-7 days for each participant. P ≤ 0.05.

	Record 1 (mean±SD)	% RDA	Record 2 (mean±SD)	% RDA	*p* - value	$ICC_{2,1}$	SEM	CV (%)	MDC
Energy Intake (kcal)	2911 ± 1185		2601 ± 1332		0.239	0.780	579.2	21.0	1605.6
Carbohydrate (g)	282 ± 81		257 ± 160		0.461	0.668	74.1	27.5	205.3
Protein (g)	172 ± 89		149 ± 87		0.110	0.871	31.2	19.5	86.5
Fat (g)	122 ± 122		105 ± 57		0.191	0.733	28.5	25.0	78.9
Vitamin A (mcg)	612.4 ± 826.3	68	860.5 ± 843.5	96	0.458	0.190	754.1	102.4	2090.1
Thiamin (mg)	1.6 ± 0.7	137	1.5 ± 1.0	127	0.739	0.130	0.8	50.8	2.2
Riboflavin (mg)	2.5 ± 1.2	195	2.3 ± 0.9	179	0.593	0.355	0.9	35.8	2.4
Niacin (mg)	47.2 ± 41.4	295	34.0 ± 12.4	212	0.335	-0.006	30.6	75.5	84.9
Vitamin B6 (mg)	4.1 ± 4.5	314	3.1 ± 1.7	235	0.483	0.023	3.3	93.6	9.3
Folate (mcg)	387.0 ± 209.8	97	416.2 ± 194.5	104	0.692	0.325	168.3	41.9	466.4
Vitamin B12 (mcg)	20.8 ± 28.0	867	11.2 ± 13.8	467	0.252	0.288	18.5	115.5	51.2
Vitamin D (IU)	1148.8 ± 3007.1	191	1220.4 ± 3013.1	203	0.221	0.998	128.7	10.9	356.7

Vitamin E (mg)	12.4 ± 8.3	83	11.0 ± 5.5	74	0.521	0.516	5.0	42.2	13.7
Calcium (mg)	1281.4 ± 1209.6	128	1349.5 ± 1189.9	135	0.699	0.896	402	30.5	1113.1
Iron (mg)	20.1 ± 9.7	251	17.4 ± 10.1	217	0.301	0.638	5.9	31.6	16.4
Phosphorus (mg)	1701.6 ± 964.0	213	1710.2 ± 855.5	214	0.966	0.767	455.7	26.7	1263.2
Potassium (mg)	3476.6 ± 2084.5	102	3352.6 ± 1361.5	99	0.809	0.578	1172.7	34.3	3250.5
Sodium (mg)	3616.3 ± 1098.4	151	3593.8 ± 2206.0	150	0.968	0.469	1297.7	35.0	3597.0

Table 4 reports individual intakes of energy, carbohydrates, protein, and fat on both food records. The values presented are the average values of three days of regular intake. Tables 5 and 6 report individual vitamin and mineral intakes for both food records, respectively. A total of 8 out of 11 participants (73%) had an energy intake below their eTEE, 8 participants (73%) also did not meet recommended carbohydrate intake, 4 out of 11 participants (36%) did not meet recommended fat intake, and 8 participants did not meet recommended protein intake. Intakes for vitamin A, vitamin E, vitamin D, and potassium were below the RDA in at least 5 out of 11 wrestlers (45%). Calcium intake was below the recommended value for athletes in a caloric deficit for 9 out of 11 participants (82%) and was below the RDA for 4 out of 11 participants (36%).

Table 4. Individual energy, carbohydrate, protein, and fat intakes averaged over 3 days for n=11 male collegiate wrestlers.

Participant	Energy Intake 1 (kcal)	Energy Intake 2 (kcal)	Carbohydrate 1 (g)	Carbohydrate 2 (g)	Protein 1 (g)	Protein 2 (g)	Fat 1 (g)	Fat 2 (g)
1	1915	3055	265	416	68	118	206	133
2	2872	3991	349	484	114	131	121	165
3	4419	4419	395	395	366	366	147	147
4	1538	568	169	55	101	45	53	17
5	2142	1814	227	196	139	117	80	57
6	1605	1212	194	132	78	72	55	41
7	1938	1466	247	131	83	92	62	58
8	3564	2743	373	268	182	129	138	125
9	3825	2293	221	102	296	220	198	101
10	3215	2408	270	171	260	161	105	110
11	4985	4648	392	486	207	187	180	204

Table 5. Individual vitamin intakes for n = 11 male collegiate wrestlers. Records 1 and 2 were separated by 4-7 days for each subject.

Subject	**Vitamin A (mcg)**		**Thiamin (mg)**		**Riboflavin (mg)**		**Niacin (mg)**		**Vitamin B6 (mg)**		**Folate (mcg)**		**Vitamin B12 (mcg)**		**Vitamin D (IU)**		**Vitamin E (mg)**	
	Rec 1	*Rec 2*	*Rec 1*	*Rec 2*	*Rec 1*	*Rec 2*	*Rec 1*	*Rec 2*	*Rec 1*	*Rec 2*	*Rec 1*	*Rec 2*	*Rec 1*	*Rec 2*	*Rec 1*	*Rec 2*	*Rec 1*	*Rec 2*
1	50	123	1.2	1.0	1.1	1.9	14.9	21.2	1.5	2.3	160	340	3.5	6.0	125	297	4.6	14.0
2	6	473	0.4	3.1	0.4	2.7	23.9	41.2	0.5	2.7	98	681	1.4	4.9	0	164	10.6	13.9
3	110	110	2.6	2.6	3.4	3.4	39.3	39.3	3.1	3.1	735	735	52.1	52.1	565	565	8.1	8.1
4	42	177	0.9	0.3	1.1	1.2	21.1	11.2	1.9	0.9	297	97	1.9	2.1	107	92	3.8	1.6
5	207	1042	2.1	1.0	3.1	1.2	163.7	23.8	16.7	2.1	195	317	91.7	6.9	376	307	16.0	6.8
6	796	882	0.9	0.7	2.7	1.9	51.6	56.1	4.3	7.4	361	219	10.7	8.3	126	331	7.1	11.0
7	617	110	1.8	1.0	2.2	1.5	24.0	27.6	1.2	1.9	356	320	4.0	12.0	80	42	8.8	7.2
8	2823	864	2.3	1.7	3.2	2.7	43.2	33.5	4.1	3.7	717	462	9.4	8.5	10200	10286	14.7	10.4
9	289	1533	1.9	0.9	4.3	2.7	39.9	41.3	3.4	3.1	378	385	15.2	6.6	446	288	26.3	23.3
10	573	2909	2.0	1.3	3.2	2.2	65.8	42.6	6.1	3.8	554	411	30.2	8.0	230	727	28.4	12.3
11	1224	1243	1.9	3.2	3.2	4.1	31.6	35.6	2.2	2.5	405	612	8.7	7.9	382	325	8.4	12.8

Table 6. Individual mineral intakes for n = 11 male collegiate wrestlers. Records 1 and 2 were separated by 4-7 days.

Participant	**Calcium (mg)**		**Iron (mg)**		**Phosphorus (mg)**		**Potassium (mg)**		**Sodium (mg)**	
	Rec 1	*Rec 2*	*Rec 1*	*Rec 2*	*Rec 1*	*Rec 2*	*Rec 1*	*Rec 2*	*Rec 1*	*Rec 2*
1	519.8	1200.4	12.2	23.7	642.9	1330.8	1043.0	3293.6	2536.8	4843.5
2	262.7	1405.3	12.1	23.2	713.8	2037.8	1664.0	3928.1	4532.2	7216.6
3	4498.6	4498.6	40.1	40.1	3565.6	3565.6	5140.1	5140.1	5382.2	5382.2
4	552.2	317.2	9.4	2.7	718.5	551.2	1587.4	1029.3	2697.6	330.7
5	1357.0	771.4	19.3	11.8	1095.2	1255.0	3022.1	2510.3	4111.8	1911.5
6	716.6	539.2	10.8	7.0	1441.0	1037.0	1760.5	1194.0	2444.7	1782.1
7	480.3	291.9	15.2	12.3	1142.6	1087.5	2363.7	2795.6	4015.0	1410.1
8	621.5	1243.5	22.6	12.8	2038.3	1812.3	4622.0	3723.7	3184.5	3232.5
9	1853.6	1194.2	29.4	18.3	2713.0	1460.9	5162.2	4265.2	3025.2	2938.8
10	1318.3	1070.2	30.2	16.7	2102.2	1904.2	7841.4	4095.0	2583.5	3965.9
11	1914.4	2312.9	19.9	22.2	2544.7	2770.0	4036.3	4904.0	5265.3	6518.2

Table 7 reports means ± SD for performance variables (Extension Peak Torque, Flexion Peak Torque, Extension: Flexion Ratio, Fatigue Index, Max Power, Time to Exhaustion, and Total Work).

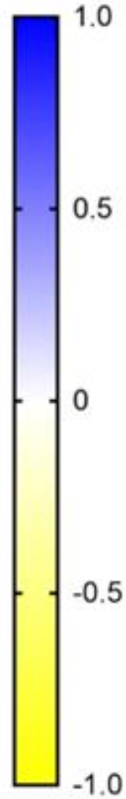
Table 7. Means (± standard deviations, SD) for leg strength, anaerobic, and aerobic performance variables in n=11 collegiate male wrestlers.

Performance Measurements	**Mean ± SD**
Extension Peak Torque ($Nm \cdot kg^{-1}$)	2.8 ± 0.4
Flexion Peak Torque ($Nm \cdot kg^{-1}$)	1.6 ± 0.2
Extension: Flexion Ratio 2	60.5 ± 12.0
Extension Fatigue Index	46.9 ± 14.7
Flexion Fatigue Index	43.5 ± 19.0
Power Max (W)	318.2 ± 38.9
Time to Exhaustion (s)	107.6 ± 47.4
Total Work (KJ)	158.9 ± 74.0

No differences were observed between starter and non-starter groups for body composition, nutrient intake, or performance variables. Therefore, correlation analyses were conducted with the composite group. Table 8 reports correlations for select variables of body composition, nutrient intake, and performance. In general, body composition variables show positive high to very high intercorrelations ($p < 0.0001 – 0.002$). Energy, macronutrient, and mineral intake were also intercorrelated with positive moderate to very high intercorrelation ($p < 0.0001 – 0.044$); however, vitamin intakes in general were not intercorrelated with other dietary intakes ($p \geq 0.05$). Performance variables showed less intercorrelation, with four out of eleven variables having no significant intercorrelations ($p \geq 0.05$). The remaining seven variables show positive moderate to high intercorrelations ($p = 0.0002 – 0.041$). In general, macronutrient intake and body composition variables demonstrated positive moderate to very high correlation ($p < 0.000 – 0.050$). Mineral intake and body composition similarly demonstrated positive moderate to high correlation ($p = 0.0004 – 0.042$). Conversely, vitamin intake and body composition variables show no significant correlations ($p > 0.05$), with the exception of a negative correlation between vitamin A intake and age ($p = 0.036$). Body composition demonstrated moderate to high positive correlations with specific performance variables ($p = 0.0002 – 0.033$). In general, moderate to high correlations were observed between nutrient intakes and performance variables ($p = 0.0003 – 0.049$), with two negative correlations between vitamin A intake and extension peak torque (PT) normalized for body weight ($p = 0.013$) and extension fatigue index ($p = 0.004$).

Table 8. Correlations between nutrient intake, body composition, and performance.

	Fat Free Mass	Estimated TEE	Estimated RMR	Energy	Carbohydrate	Protein	Fat	Calcium	Iron	Postassium	Sodium	Extension Peak Torque	Flexion Peak Torque	Max Power	Total Work
Fat Free Mass	1.00	1.00	1.00	0.89	0.72	0.65	0.89	0.71	0.69	0.83	0.87	0.81	0.87	0.68	0.86
Estimated TEE	1.00	1.00	1.00	0.89	0.72	0.65	0.89	0.71	0.69	0.83	0.87	0.81	0.87	0.68	0.86
Estimated RMR	1.00	1.00	1.00	0.89	0.72	0.65	0.89	0.71	0.69	0.83	0.87	0.81	0.87	0.68	0.86
Energy	0.89	0.89	0.89	1.00	0.91	0.70	0.97	0.80	0.86	0.87	0.95	0.84	0.81	0.68	0.88
Carbohydrate	0.72	0.72	0.72	0.91	1.00	0.41	0.89	0.61	0.72	0.63	0.93	0.73	0.76	0.58	0.82
Protein	0.65	0.65	0.65	0.70	0.41	1.00	0.58	0.92	0.88	0.82	0.53	0.65	0.49	0.44	0.49
Fat	0.89	0.89	0.89	0.97	0.89	0.58	1.00	0.65	0.75	0.87	0.95	0.76	0.80	0.75	0.90
Calcium	0.71	0.71	0.71	0.80	0.61	0.92	0.65	1.00	0.90	0.74	0.63	0.76	0.66	0.43	0.67
Iron	0.69	0.69	0.69	0.86	0.72	0.88	0.75	0.90	1.00	0.83	0.77	0.74	0.64	0.55	0.63
Postassium	0.83	0.83	0.83	0.87	0.63	0.82	0.87	0.74	0.83	1.00	0.78	0.70	0.65	0.65	0.74
Sodium	0.87	0.87	0.87	0.95	0.93	0.53	0.95	0.63	0.77	0.78	1.00	0.74	0.83	0.70	0.82
Extension Peak Torque	0.81	0.81	0.81	0.84	0.73	0.65	0.76	0.76	0.74	0.70	0.74	1.00	0.74	0.68	0.76
Flexion Peak Torque	0.87	0.87	0.87	0.81	0.76	0.49	0.80	0.66	0.64	0.65	0.83	0.74	1.00	0.42	0.88
Max Power	0.68	0.68	0.68	0.68	0.58	0.44	0.75	0.43	0.55	0.65	0.70	0.68	0.42	1.00	0.56
Total Work	0.86	0.86	0.86	0.88	0.82	0.49	0.90	0.67	0.63	0.74	0.82	0.76	0.88	0.56	1.00



Correlations between the macronutrient and mineral intake and performance variables are displayed in Figures 2 and 3. Significant correlations are indicated by bolded p-values (p = 0.0001 – 0.049).

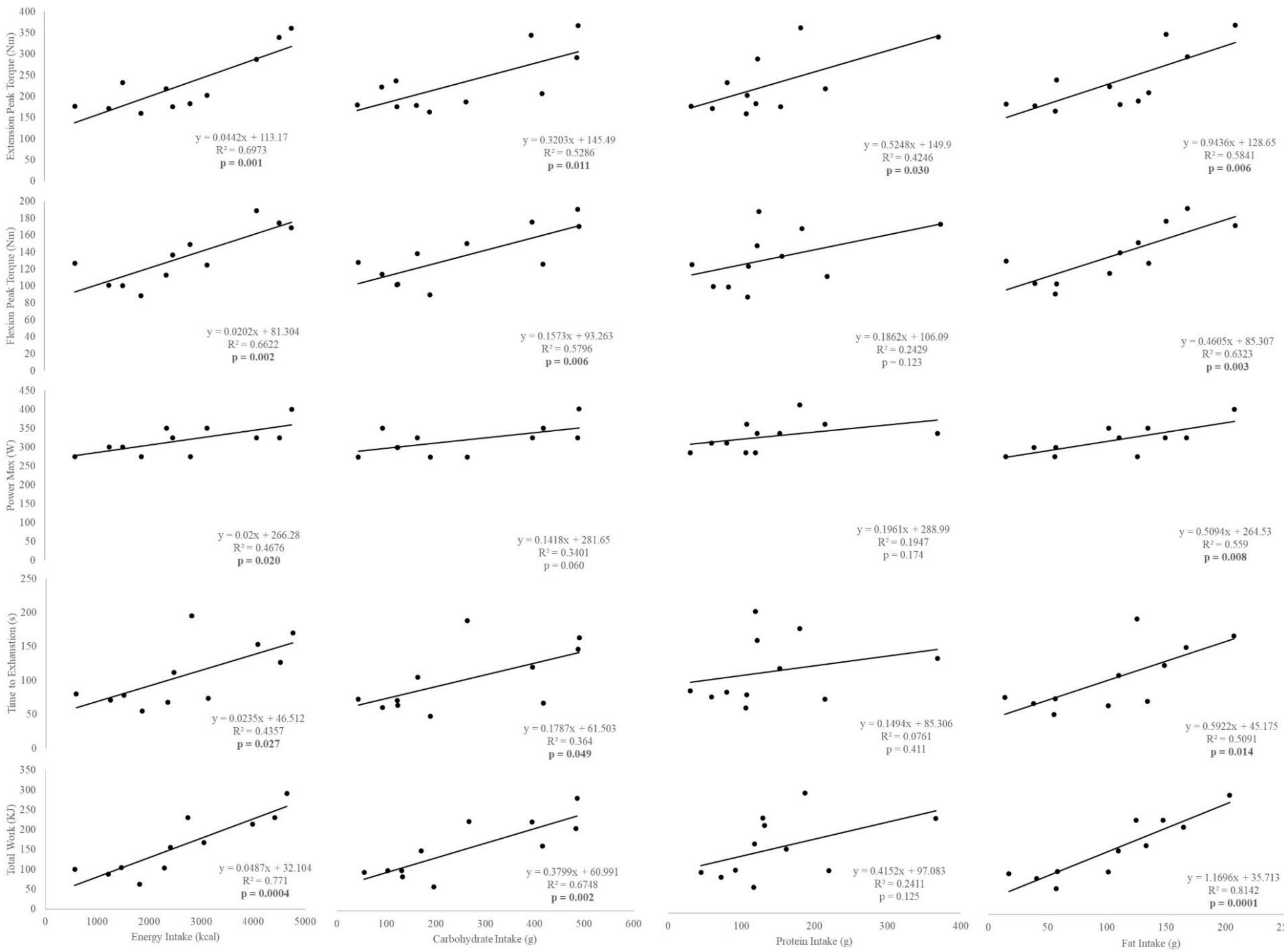


Figure 2. Scatterplots demonstrating correlations between performance variables and macronutrient intakes. Significant correlations are indicated by bolded p values ($p \leq 0.05$) and show a positive relationship between performance and macronutrient intake.

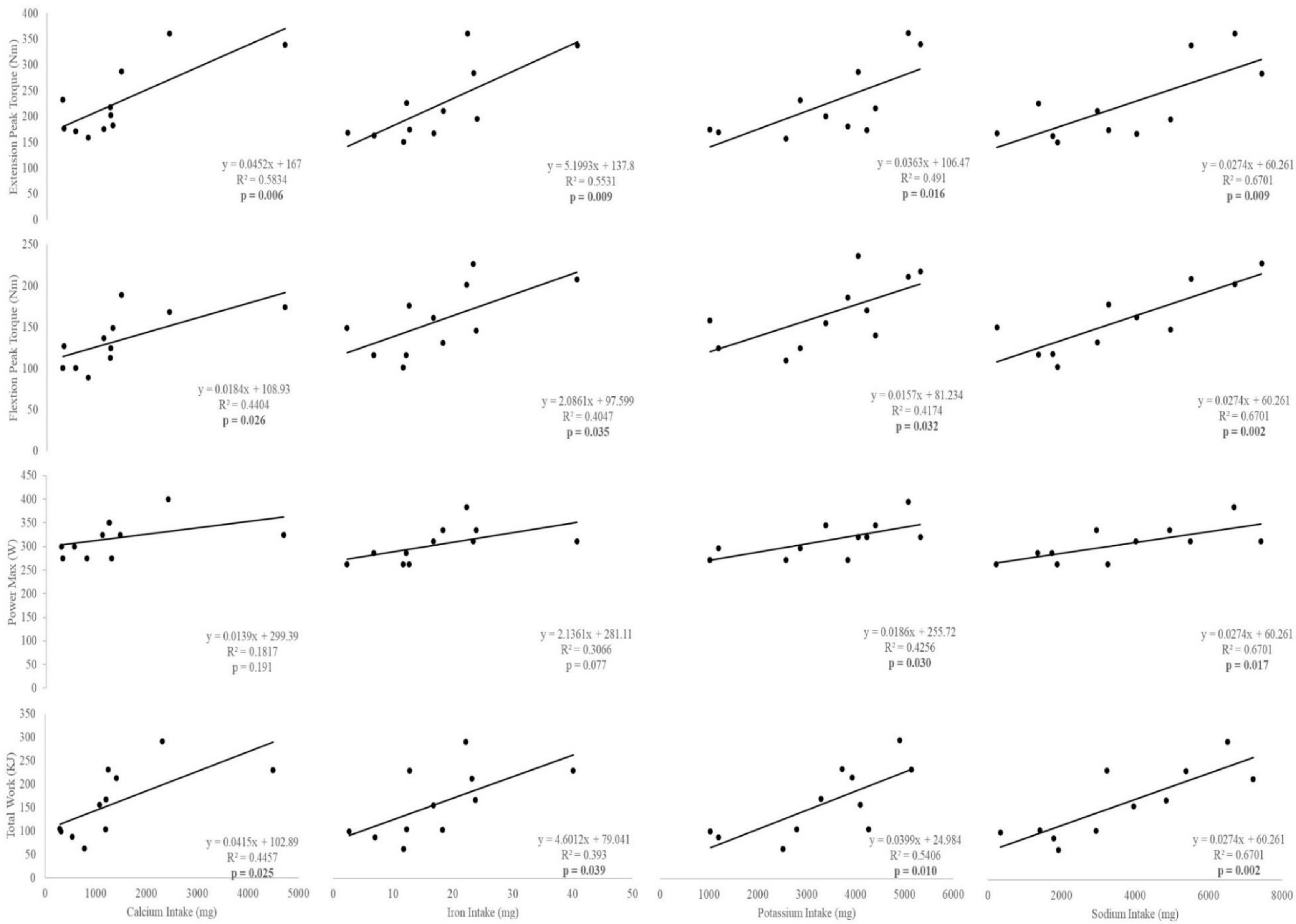


Figure 3. Scatterplots demonstrating correlations between performance variables and mineral intakes. Significant correlations are indicated by bolded p values ($p \leq 0.05$) and show a positive relationship between performance and mineral intake.

For the significant relationships between nutrient intake and athletic performance, partial correlations were calculated to remove the influence of concurrently related body composition variables. No correlations remained significant after partialing out FFM and eRMR ($p > 0.05$). Only the correlation between fat intake and total work remained significant when weight was partialed out ($|r_{Fat,Total\ Work.weight}| = 0.640$, $p = 0.046$). Four correlations remained significant when height was partialed out: carbohydrate intake and total work ($|r_{Carbohydrate\ Intake,Total\ Work.Height}| = 0.734$, $p = 0.16$), energy intake and total work ($|r_{Energy\ Intake,Total\ Work.Height}| = 0.693$, $p = 0.026$), fat intake and total work ($|r_{Fat\ Intake,Total\ Work.Height}| = 0.729$, $p = 0.017$), and iron intake and extension PT ($|r_{Iron\ Intake,EXT\_PT.Height}| = 0.692$, $p = 0.027$).

CHAPTER V: Discussion

The main finding of this study is a nutritional and physiological profile of NCAA Division I male wrestlers. This is the first study to our knowledge to perform a dietary analysis of Division I wrestlers. The participants included at least one athlete competing in every weight class with the exception of the 157 pound class. As such, body mass ranged from 64.4 kg to 122.0 kg, with FFM ranging from 61.6 kg to 94.8 kg, and fat mass ranging from 3.2 kg to 27.2 kg (Table 1). The mean energy intake was 2,601 kcal, with eight out of eleven participants not meeting eTEE.[45] Additionally, all participants failed to meet general recommendations for at least one macronutrient.[9] Mean macronutrient distribution consisted of 49% of calories from carbohydrates, 23% from protein, and 37% from fats (Table 3). These findings partially conflict with our first hypothesis since the wrestlers in this study were deficient in both energy and macronutrients. When normalized to body mass, mean extension and flexion PT was 2.8 $Nm \cdot kg^{-1}$ and 1.6 $Nm \cdot kg^{-1}$, respectively. Mean power max on the aerobic graded exercise test was 318.2 W, and mean time to exhaustion for the anaerobic exhaustion test was 107.6 seconds (Table 7). In line with our second hypothesis, macronutrient and mineral intakes showed positive correlations with measurements of body composition and performance. However, when accounting for body composition, the relationships between nutrient intake and performance were no longer significant, indicating that primarily body composition, in conjunction with nutrition, may have a large influence on wrestling performance.

In general, the athletes in this study failed to meet recommendations for nutrient intake. Mean energy intake on the second food record was 2,601 kcal, about 1,200 kcal lower than mean eTEE. Specifically, eight out of eleven participants (73%) had energy intakes below calculated eTEE, while five athletes (45%) had energy intakes lower than eRMR (Table 4). Additionally, mean carbohydrate intake was 257 g, or about 3.1 $g \cdot kg^{-1}$, whereas mean protein intake was 149 g, or about 1.8 $g \cdot kg^{-1}$. These findings are similar to the Lingor and Olson paper evaluating dietary intake of Division III collegiate athletes. They reported a mean energy intake of 2,000 $kcal \cdot kg^{-1}$ and 2,387 $kcal \cdot kg^{-1}$ during two separate weeks, and an eTEE of 3,140 $kcal \cdot kg^{-1}$. Similarly, mean carbohydrate and protein intake was low based on general recommendations for athletes.[9] A carbohydrate intake of 3.0 $g \cdot kg^{-1}$ has been suggested as the minimum daily intake required for athletes of low-intensity, skill based sports.[46] While the participants of the current study are meeting this minimum intake, wrestlers likely need an intake closer to the 6-10 $g \cdot kg^{-1}$ suggested for training consisting of moderate to high intensity exercise of 1-3 hours a day,[46] indicating these athletes are likely lacking the energy required for optimal performance. A protein intake of 1.8 $g \cdot kg^{-1}$ may be adequate with proper energy intake; however, a higher intake of 2.3-2.5 $g \cdot kg^{-1}$ has been suggested to facilitate FFM maintenance for athletes in an energy deficit.[30,47] If the current energy deficits observed are sustained, these athletes may be at risk of losing FFM, or potentially developing relative energy deficiency, which can negatively impact performance, as well as result in a wide array of general health factors.[48]

While this is concerning, these dietary records were purposely taken in the pre-season as the athletes were preparing for the competition season. Thus, most of the participants, excluding heavyweights and one injured wrestler, were aiming to lower their body mass, which should be considered when evaluating dietary intake. However, the wide differences in macronutrient distribution between each participant highlights the lack of recommendations for optimal strategies for this population to attain this goal. In the present study, carbohydrate intake ranged from 18% to 54%, protein intake ranged from 15% to 38%, and fat intake ranged from 28% to 41%. This reinforces that more research is needed to establish nutritional recommendations for safe and effective weight loss prior to competition season. Furthermore, with more insight into the dietary practices of wrestlers during the competition season, recommendations for each stage of the weight cycle may be determined.

The mean BF% calculated for the wrestlers in this study was 8.83% (Table 3), which is similar to reported BF% for collegiate and senior level wrestlers[11,15,17–19] and athletes of other combat sports.[49–51] There is less agreement with previous studies for lean mass, possibly due to differences in methodology, as previous studies have reported FFM, lean mass, or muscle mass as a marker of body composition. Additionally, the individual nature of a weight class sport can largely influence FFM composition in athletes, with the potential for variation throughout the different stages of a season, making comparisons across studies difficult. Previous reports have not identified body composition differences as important criteria to accurately predict competitive level or success.[17,18] This observation, along with the fact that BF% measurements are similar among wrestlers at multiple levels, may reinforce the foundational importance of body composition to the sport of wrestling. It is common practice for combat sport athletes to engage in RWL techniques prior to competition in order to compete at a weight class lower than their natural weight.[26,27,52] Therefore, it may be advantageous for athletes to lower their body fat content to minimize the amount of weight lost before each competition. However, despite having a low body fat percentage, the wrestlers in this study, with the exception of those in the heavyweight weight class, were still on average 7.1 kg (15.6 pounds) heavier than their chosen weight class. This indicates that these athletes still have a relatively large percentage of their body mass to manipulate once they reach the competition season.

Additional goals during preseason typically include increasing muscular strength and aerobic capacity, while anaerobic capacity remains a focus throughout the year. The wrestlers in the current study had a mean MVIC flexion PT of 1.63 $Nm \cdot kg^{-1}$, which was similar to reference values reported for athletes of various sports; however, their extension PT of 2.78 $Nm \cdot kg^{-1}$ was lower than the reference values.[53] Similarly, isokinetic extension and flexion PT (2.50 $Nm \cdot kg^{-1}$ and 1.29 $Nm \cdot kg^{-1}$, respectively) were lower than values reported for American football players (2.90 $Nm \cdot kg^{-1}$ and 1.94 $Nm \cdot kg^{-1}$, respectively)[54] and professional soccer players (3.17 $Nm \cdot kg^{-1}$ and 1.77 $Nm \cdot kg^{-1}$, respectively).[55] While lower body strength is important for wrestlers, these athletes must attain a balance between upper and lower body strength rather than focus on raw strength.[56] While this balance is also important for other sports such as American football and soccer, these sports likely rely more on lower body strength, lending to the higher reported values.

The mean power max attained on the graded exercise test in the current study was 318.18 W (Table 7). Mean lactate concentration pre and post the graded exercise test was 2.91 $mmol \cdot L^{-1}$ and 9.93 $mmol \cdot L^{-1}$, respectively Although a good aerobic base is valuable for wrestling, anaerobic power is especially important for wrestling performance, and may be a better predictor of success than aerobic capacity.[56] Due to differences in methodology, comparisons to previous research performed in wrestlers is difficult. Previous studies have reported mean and peak power achieved during specific anaerobic tests,[11,13–15,17–19] while the current study measured TTE and TW. The test utilized in this study allowed participants to reach exhaustion and was meant to simulate a two- or three-minute wrestling period, which may be more applicable than a 30 second Wingate. As Chaabene et al concludes, there is no designated wrestling specific anaerobic test,[56] although attempts have been made to create one.[57] A wrestling specific anaerobic test, similar to the Pittsburgh Wrestling Performance Test used by Utter et al.,[57] or the special endurance test used by Cieśliński et al.[18] with the addition of heart rate measurements, such as in the special judo fitness test,[58] could be beneficial to analyze the effectiveness of different training programs, or help measure the impact of different RWL techniques on wrestling performance.

Wrestling is a dynamic sport that relies on a balance between numerous performance factors, rather than having a singular focus. An additional factor that likely impacts all aspects of performance is nutrient intake. If utilized correctly, nutrition can help to improve performance. For example, evidence suggests that long-term protein supplementation may enhance muscle hypertrophy and strength gains when paired with adequate resistance training.[59] Furthermore, Areta et al. found that 80 g of protein consumed within 12 hours following resistance training increased muscle protein synthesis (MPS), and that the MPS response is greatest when four doses of 20 g are consumed every 3 hours.[60] This would indicate that specific strategies are needed to elicit the optimal response to training. Since resistance training and strength are not typically a focus during competition season, it may be especially important to consume adequate amounts of protein, at the proper time in order to maintain FFM. Conversely, Michalczyk et al. found that a low-carbohydrate ketogenic diet reduces total work capacity achieved on an anaerobic test for male athletes,[32] indicating that performance detriments may result from improper nutrition strategies. While none of the present athletes were consuming a ketogenic diet, their carbohydrate intake is low enough to speculate that their anaerobic capacity may be suffering, which would likely detriment wrestling performance.[56]

Despite the associations between nutrition and performance, and the particular importance of intake for combat sports, few studies have examined the relationships between nutrient intake and performance in wrestlers. Nevertheless, in the present study there were several significant correlations between nutrient intake and performance variables, specifically showing moderate to very high relationships between energy, carbohydrate, and fat intake with isometric strength and anaerobic capacity (Table 9, Figure 2, Figure 3). However, FFM accounted for most of the significance between nutrient intake and performance, suggesting that nutrition in tandem with body composition may influence performance for this population more than either factor separately. This aligns with wrestlers' goal to minimize body fat, while maintaining or maximizing FFM.[61] Additionally, previous studies have reported positive associations between fat free mass and anaerobic peak power (r=0.75)[34] and indications of the detrimental effect of higher body fat on performance, including a negative relationship between BF% and peak power (r=-0.36),[34] and a positive relationship between BF% and 300-yard shuttle time (r= 0.69).[62] Therefore, nutrient intake may be an indirect influence on performance for these athletes, especially due to its impact on body composition.

This study demonstrates that wrestlers are likely in an energy deficit leading up to the competition season. Although an energy deficit is likely necessary for these athletes to make weight, it may lead to macro- or micronutrient deficiencies which could detriment performance as well as health. Additionally, maintaining high FFM may be advantageous for wrestling performance, particularly while striving to make weight. While many wrestlers have already achieved high FFM and low BF% measurements, a prolonged energy deficit throughout the season can lead to loss of FFM. Despite the importance of nutrient intake to the sport, many wrestlers lack an optimal strategy that allows them to maximize performance while making weight. In order to establish nutrition recommendations, future research should evaluate the impact of different long term weight cutting and RWL techniques on body composition and performance measurements. This may provide the foundation needed to examine and develop nutrition recommendations to guide optimal strategies for athletes to make weight and manipulate body composition while maintaining performance and general health. Additionally, monitoring nutrient intake and performance outcomes can allow coaches and health professionals to create individualized recommendations for athletes to optimize performance while managing weight cutting phases.

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