The Effect Cutting Weight Has on Bone Mineral Density in Male High School Wrestlers

By

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ABSTRACT

Weight-bearing physical activities can promote bone mineral density (BMD), but wrestlers who maintain dietary restrictions to compete in a lower weight class may be at risk for low BMD. The relationship between BMD and body mass index (BMI), percent body fat (%BF) and weight classes, respectively, in male high school wrestlers was investigated in this study. Existing data from 137 male wrestlers were analyzed. Body composition and BMD measurements were analyzed via DEXA Hologic Discovery, height was measured via Seca Stadiometer, and weight was measured via Seca Digital scale. There were no statistically significant relationships between BMD and weight class ($\chi 2(12, N = 137) = 5.128a, p = .954$), BMD and BMI ($r_{pb} = .103, n = 137, p = .231$), or %BF and BMD ($r_{pb} = .007, n = 137, p = .934$). Although current data did not show a significant relationship with BMD, further on a potential relationship between low BMI and low BMD is needed. It is also important coaches and wrestlers are educated on balancing nutritional needs and weight.

TABLE OF CONTENTS

LIST OF TABLES

APPENDIX

CHAPTER I

INTRODUCTION

Osteoporosis is a skeletal disorder resulting from a significant decrease of bone mineral density (BMD) which can increase an individual's risk of fracture (Fonseca et al., 2014; Rizzoli et al., 2010). Low BMD is a significant health concern for the older population. Rizzoli et al. (2009) explained osteoporotic hip fractures that occur after the age of 50 years can significantly decrease an individual's lifespan. Hodges et al. (2019), explained that the most important time for bone growth is during the prepubertal and early puberty stages. This is due to increased hormonal changes that occur throughout the body such as an increased production of growth hormone, thyroid hormones, and sex hormones including testosterone and estrogen (Stagi et al., 2013). Hodges et al. (2019) also noted that roughly 95% of peak bone mass is accumulated by the age of 16 years. An important factor to take into consideration is that the higher an individual's peak bone mass is in their young adulthood, the larger a decrease in BMD they can sustain in their elderly years without developing osteoporosis (Stagi et al., 2013). Obtaining the largest peak bone mass is what makes prioritizing pubertal changes an important life changing factor that can determine one's chances of getting osteoporosis later in life.

Factors That Contribute to Bone Mineral Density

Diet plays a significant role with improving BMD especially during the adolescent period. Calcium is known as a primary nutrient for maximizing bone development (Ma et al., 2007), and children need calcium to have adequate bone remodeling (Hodges et al., 2019). Silva et al. (2015) discussed calcium rich diets are also shown to significantly improve BMD, and those who lack calcium in their diet are more likely to be diagnosed with osteoporosis. Those who have insufficient calcium intake in their diet are at risk of increasing parathyroid hormone which can negatively affect BMD (Dawson-Hughes, 2003).

There are many types of PA that can promote BMD. Research has shown that weight-bearing PA such as plyometrics (Çay et al., 2018), resistance training (Duplanty et al., 2018), and combat sports (Yücel & Sebiha 2016) can increase BMD. Weight-bearing exercises stimulate the increased formation of osteoblasts to promote the buildup of BMD (Yuan et al., 2015). According to Stagi et al., (2013) weight-bearing exercises also inhibits the production of osteocytes, which inhibit bone formation. Additionally, an increase in weight-bearing PA at a younger age can increase peak bone mass at an earlier point in life. One group of athletes that may be unique, however are wrestlers.

Wrestling is primarily an anaerobic combat sport that has been shown to have increases in BMD due to the large static component (Yücel & Sebiha, 2016). Additionally, there is evidence that demonstrates wrestler's higher levels of BMD compared to other sports (Bozkurt, 2010). Wrestlers regularly restrict their dietary intake to be at a specific weight to compete in each weight class (Pettersson et al., 2012). It is unknown how this can affect an individual's BMD, especially during the growth period of an adolescence life. In fact, there is a correlation with low BMI and low BMD. Savvidis et al., (2018) explained that Individuals with higher levels of BMI are linked with higher levels of BMD. Wrestlers who are at a lower BMI and maintaining a strict dietary restriction may be at risk for low BMD.

Purpose of Study

Therefore, the purpose of this study is to examine the effect excessive weight loss has on BMD in male high school wrestlers. A secondary purpose is determining the statistically significant difference of wrestlers falling in the low BMD category across weight classes. Will BMD look significantly different among weight classes in male high school wrestlers, and if so, will BMD be significantly lower in the lower weight classes that require individuals to drastically minimize their weight?

Significance of Study

This study can be found to be significant because it is important to know whether adolescent wrestlers are decreasing their BMD during the time where they should be acquiring the highest amount in their lifetime. If this is the case, individuals can be increasing their chances of having osteoporosis later in life. This will significantly increase an individual's risk of fracture and can cause them to be more dependent. Having this increase in fracture risk, can also limit an individual's physical activity level. This will be counterproductive in terms of increasing BMD. These are some of the many reasons why this demographic should be studied.

CHAPTER II

LITERATURE REVIEW

This review begins with background information on the structure and formation of bone. This includes the processes of intramembranous and endochondral ossification, and the importance of proper bone remodeling. Next, modifiable, and nonmodifiable risk factors that can improve or negate bone health such as age, ethnicity, gender, dietary considerations, and types of physical activity (PA) are addressed. The review then transitions into an overview of wrestling and how the sport can benefit BMD. Accompanying this information will be information on the wrestling practice of "cutting weight" and how this can affect BMD. The review concludes with an overall summary.

Anatomy and Physiology of Bone Growth

Human bone is a form of connective tissue that serves many purposes and functions to help sustain human life. According to Moreira et al. (2019), the three main functions bone serves are to provide support and attachment points for muscle, protect organs, and store calcium and phosphates. Along with these functions, bone is also responsible for three continuous phases that change bone shape due to mechanical loads placed upon the body (Hart et al., 2020; Moreira et al., 2019). The cells responsible for maintaining the composition of bone are osteoblasts, osteocytes, and osteoclasts. Raisz (1999) explained bone remodeling is broken down into three phases: resorption, in which mesenchymal cells interact with hematopoietic cells to create osteoclasts that breaks down "old bone," reversal, where mononuclear cells form on the surface of the bone, and formation, when mesenchymal stem cells differentiate into osteoblasts to form new bone. Hart et al. (2020) noted complications with bone remodeling can increase risk for osteoporosis or osteopenia.

The formation of bone begins during embryonic development and continues until approximately age 25 years (Breeland et al., 2021). This process is referred to as bone ossification or osteogenesis. Saggese et al. (2002) discussed that bone mass roughly doubles between puberty and young adulthood due to metabolic, mechanical, and nutritional stresses placed to the bone. The first 2 years of life and puberty are the most common peaks of bone turnover, and approximately 90% of adult bone mineral is accumulated by the end of adolescence. The accumulation of bone mineral during puberty is also a determining factor for peak bone mass, which can prevent the risk of osteoporotic fractures later in life (Saggese et al., 2002).

There are two pathways the body takes to achieve osteogenesis: intramembranous and endochondral ossification. Intramembranous ossification occurs in fibrous connective tissue and is known for forming flat bones in the skull, mandible, clavicle, and the subperiosteal surface (Moreria et al., 2019). According to Aghajanian and Mohan (2018), intramembranous ossification skips the formation of cartilage by transforming mesenchymal cells directly into osteoblasts. Simply put, skipping the formation of cartilage speeds up the process of bone formation. Endochondral ossification is responsible for the formation of long bones, which begins in the fetus and continues through puberty (Zaretsky et al., 2021). During endochondral ossification, mesenchymal cells transform into chondrocytes to form cartilage for the structure of the bone (Breeland et al., 2021). Bone ossification lays down the foundation for optimal bone growth which can be either encouraged or hindered depending on certain external and internal factors placed on the body.

Factors that Impact Bone Health

The amount of BMD that an individual has is the main factor used to diagnose osteoporosis. Adults with a BMD score that is 2.5 standard deviations (SD) or lower from the mean of the population for young adults (age 30 years) are classified as having osteoporosis (Klibanski et al., 2001), and osteopenia is used to classify individuals who have low BMD for their age. Children, on the other hand, are classified as having low BMD with a z-score ≤ -2.0 SD from the mean without history of two or more long bone fractures by the age of 10 years and without three or more long bone fractures by the age of 19 years (Trovato & Dietzan 2021). Atalar et al. (2009), Kalkwarf et al., (2007), and Rulu et al., (2019) identified some modifiable and non-modifiable factors that can promote or impede overall bone health such as fracture history, age, hormone production, ethnicity, height, body mass, pubertal development, diet, PA, cigarette smoking, and alcohol consumption.

Roughly 50% of children between the ages of 5 and 18 years' experience a fracture. There is a correlation between low BMD and an increased number of fractures and smaller bone size, respectively, in children and adolescents (Rizzoli 2010). In adults, a decrease in PA, decreased estrogen and testosterone production, and increase in body mass index, can all contribute to a decrease in BMD and increase the risk for osteopenia and osteoporosis (Rulu et al., 2019 & Snyder et al., 2017). According to Kalkwarf et al. (2007), African Americans have significantly greater BMD of the whole body, hip, and radius than non-African Americans at all ages, due to an elevated height, weight, and rate of pubertal development. If an individual after the age of 50 years has an osteoporotic fracture, females have a 50% chance of having another osteoporotic fracture, while males have a 20% chance (Rizzoli et al., 2009). Atalar et al. (2009) and Rulu et al. (2019) found an inverse relationship with age and BMD. Bone mineral density was significantly lower in women post menopause with a possible correlation with a decrease in estrogen production (Rulu et al., 2019). While these factors are beyond one's control, there are several controllable factors related to BMD.

One controllable influencer of BMD is dietary calcium intake. The recommended dietary intake for children 4-8 years old is 800 mg (Greer & Krebs 2006), and 1,300 mg for children between the ages of 9-18 years (Cormick & Belizán 2019). Atalar et al. (2009) refers to calcium rich diets and higher amounts of weight-bearing PA as modifiable factors that have a positive effect on BMD. Calcium is the primary nutrient for proper bone development and preventing osteoporosis (Ma et al., 2007). Children and adolescents create new bone at a significant rate and require adequate calcium to undergo bone remodeling (Hodges et al., 2019). According to Dawson-Hughes (2003), insufficient calcium consumption negatively affects BMD by releasing an increased amount of parathyroid hormone. Parathyroid hormone causes the excretion of calcium from the bones, which ultimately leads to bone resorption and can increase the risk of fracture. Silva et al. (2015) found older women who regularly consumed a rich source of calcium such as cow milk showed fewer signs and symptoms for being at risk of osteoporosis or osteopenia than older women who did not consume cow milk regularly. Adequate calcium intake has the strongest influence on BMD during the prepubertal and early puberty stages (Atalar et al., 2009), as only small increases in BMD are seen afterwards from increased calcium consumption (Hodges et al., 2019). Hodges et al. (2019) also noted individuals who are lactose intolerant are more likely to have a lower BMD, due to the lack of dairy products within their diets.

Physical activity has a positive linear relationship with BMD (Atalar et al., 2009). Bone mass is generally higher in young adult athletes due to the amount of PA they perform, especially with more weight bearing activities (Hinrichs et al., 2010). Researchers found that men and women (age 17-30) who performed power/combat sports had the highest BMD values in the proximal femur and the lumbar spine, compared to runners, cyclists, triathletes, team sport athletes and ballet dancers. Langsetmo et al. (2012) explained an increase in BMD and decrease in BMI are strongly associated with an increase in PA. The researchers further discussed this increase in PA can contribute to a decrease in the obesity epidemic without an increased risk of bone loss. Skeletal unloading is strongly correlated with a decrease in BMD, which leads to the conclusion that weight-bearing exercises are important for the production and maintenance of BMD (Atalar et al., 2009; Rizzoli et al., 2009). A study by Rector et al. (2009), compared the effects of weight-bearing and non-weight bearing exercises on BMD and found individuals between the ages of 19 and 45 years that participated in resistance training had significantly greater amounts of whole-body BMD. This supports the positive relationship between bone loading exercise and increased BMD.

Modifiable risk factors that have a negative effect on BMD are smoking, alcoholic consumption, and low BMI (Atalar et al., 2009; Trivedi & Khaw 2001). Cigarette smoking negatively effects BMD by decreasing the rate of absorption of calcium into the bones (Ghadimi et al., 2018), which is primarily due to a significant reduction of sex steroid production (Atalar et al., 2009). Individuals with a higher BMI were found to have an increased mechanical load on their bone structure which increases BMD and decreased risk of fracture (Atalar et al., 2009; Savvidis et al., 2018). On the other hand, a decreased BMI can reduce BMD due to the reduction of mechanical load on the skeleton (Shapses & Sukumar 2012). This information is valuable and useful to keep in mind with athletes that must deal with weight restrictions and limitations, such as in wrestling. Since there are numerous factors that must be taken into consideration for proper bone development, especially during adolescence where 90% of bone mineral is accumulated (Saggese et al., 2002), it is important to maintain proper diet, minimize fractures, and perform an adequate amount of PA. The next section includes the importance of PA and types of PA that are most ideal for maximizing BMD.

Effect Exercise has on Bone Remodeling

Mesenchymal stem cells (MSC's) are multipotent and can differentiate into various cells including osteoblasts, chondrocytes, myocytes, and adipocytes. According to Yuan et al. (2015), mechanical loading via exercise promotes the formation of osteoblasts from MSC's, which has been shown to increase BMD. Weight-bearing exercises can also inhibit MSC's from entering adipogenesis, which can assist in prevention of factors that can progress bone loss (Yuan et al., 2015). Another factor that can impede bone production is a protein secreted by osteocytes called sclerostin, and it is further discussed by Stagi et al. (2013), that resistance training can decrease the secretion of this protein and allow bone formation to increase. Stagi et al. (2013) also explained PA increases BMD during childhood and adolescents and could result in significant increases in peak bone mass if initiated earlier in life.

Impact of Running on Bone

Running is a weight-bearing exercise that may produce higher levels of BMD, especially at the femoral neck (Mussolino et al., 2001). In a comparison of runners and cyclists, Rector et al. (2008) found the mechanical loading on the body from running provided a significantly greater amount of BMD than a non-weight-bearing exercise such as cycling. The researcher concluded running and jogging is an exercise individuals should incorporate into their lifestyle to improve BMD. Mussolino et al. (2001) found young and middle-aged males who ran at least one time a month had higher levels of BMD than those who did not. Additionally, BMD was highest in individuals who ran 9 times or more in one month. Fredericson et al. (2007) compared the difference in BMD among elite male distance runners and sedentary male individuals between aged 20-30 years. Researchers found the elite runners showed higher levels of BMD to the calcaneus, which can benefit an individual in the later stages of life when balance becomes an issue. The research shows that running helps increase BMD, more than non-weight-bearing exercises and being sedentary.

Impact of Resistance Training on Bone

Individuals who participate in resistance training exercises such as power lifting have noticeable increases in BMD and are less likely to be diagnosed with osteoporosis (Duplanty et al., 2018). Almstedt et al. (2011) found resistance training with movements such as a squat or a deadlift, significantly improved BMD in young men. In a previous study, college-aged male powerlifters developed a greater amount of BMD in the lumbar spine and whole body than those who participated in less than 2 hours of PA per week (Tsuzuku et al., 1997). Further the increase in BMD was specifically associated with squats and deadlifts, due to the force being applied to the shoulders in both exercises. Similar changes in BMD are observed with cross-training, where runners that incorporate resistance training have higher overall BMD than those who do not (Duplanty et al., 2018). According to Whipple et al. (2004), when implementing moderate intensity resistance training in young males, there was a reduction in bone resorption and an increase in bone formation. Implementing resistance training into a lifestyle will improve total BMD and decrease risk of osteoporosis.

Impact of Plyometrics on Bone

Plyometric training is known as an effective, modifiable training regimen for athletes that can increase overall power and prevent knee injuries (Stojanović et al., 2017). It has been found that individuals who perform high intensity plyometric training activities have higher BMD of the lower extremities than those who did not incorporate plyometrics into their routine (Witzke & Snow, 2000). Hinton et al. (2015) showed an increase in BMD via plyometric training in the lumbar spine and whole body for men with an average of 44 with low BMD (T-Score > -2.5 SD). Çay et al. (2018) found runners who incorporated explosive power movements such as push-ups and jump squats into their training regimen were found to have significantly higher levels of BMD. A similar study showed sports that incorporate an increased amount of plyometrics resulted in higher BMD in the lower extremities, even with a lower training frequency (Nordtsröm et al., 2009). The significant increase in BMD in the lower extremities is associated with the mechanical loading and stress that is being placed on the lower extremities. Plyometrics is an effective way to increase BMD of the whole body and can be used for all ages.

Wrestling

Most sports rely on one or two types of training styles, but a sport that incorporates a wide variety of training styles is wrestling. This sport is primarily anaerobic but also includes aspects of aerobic fitness that are essential to have a competitive advantage over an opponent. Wrestling does include a wide range of explosive movements when taking down an opponent (Yücel and Sebiha 2016). Additionally, Yücel and Sebiha (2016) credited the increase in BMD for wrestlers from an increased frequency and duration of training bouts, and not from the length of the matches themselves (6 minutes or less). According to Sabillah et al. (2022), incorporating plyometric exercises such as box jumps can significantly increase leg power in wrestling athletes. What is most interesting about this sport is that it utilizes a wide range of methods that can increase BMD, but based on previous information, caloric restriction, which is also characteristic of wrestlers, will not only hinder performance but can also decrease overall BMD.

As you can see, there is a wide variety of exercises that has a positive effect on BMD. Running provides enough bone loading that should increase BMD (Rector et al., 2008). There are even greater increases with the addition of exercises that include more resistance (Duplany et al., 2018). When focusing on the BMD of the lower extremities, it is also imperative to incorporate explosive movements such as plyometric movements (Witzke & Snow, 2000). Yücel and Sebiha (2016) explained that wrestlers utilize multiple training methods that should all have a positive influence on BMD. Research shows that bone loading exercises of any kind should increase BMD.

Wrestling Information

The information above shows great examples of multiple different variations of exercise that can influence a greater potential growth of BMD in different areas of the body. Combat sports, such as wrestling, are great forms of physical activity that includes many different movements that should have a positive influence on BMD. Wrestling is an anaerobic combat sport that requires individuals to pin their opponents to the ground via grappling, throwing, and clinching. Yücel and Sebiha (2016) discussed wrestling requires individuals to utilize isometric contractions while performing various holds to proceed to an advantageous position which applies an excessive amount of pressure on the bones. There is evidence that wrestlers have higher BMD than soccer players (Yücel & Sebiha 2016), physical education students (Długołęcka et al., 2019), taekwondo athletes, and runners (Bozkurt, 2010). Midorikawa et al. (2021) and similarly, Tsukahara et al. (1999), found sumo wrestlers had high levels of BMD due to their excessive body mass, which is different from the previous study with wrestlers because there is not a caloric restriction in place for sumo wrestlers.

As previously stated, all athletes need to prioritize optimal nutritional diets in order to succeed in their respective sports. Wrestlers may have trouble maintaining this priority due to the involvement of weight classes. Weight classes are used in sports to even the playing field for competitors. There are 14 weight classes in high school men's wrestling (106 lbs., 113 lbs, 120 lbs., 126 lbs., 132lbs., 138 lbs., 145 lbs., 152 lbs., 160 lbs., 170 lbs., 182., 195 lbs., 220 lbs., 285 lbs.). Individuals are required to stay under the respective weight to wrestle for the desired weight class. Having to maintain a certain weight in order to compete may require a level of dietary restraint (Pettersson et al., 2012). This may counteract the benefits of training if an athlete is malnourished, and can result in a negative effect on nutritional, hormonal, and immune function. A malnourished athlete can lead to relative energy deficiency in sports and even low BMD (Duplanty et al., 2018), especially with the volume of training typical of wrestling.

Wrestlers often attempt to lose body weight to compete in lower weight classes to have an advantage over their opponents. Common ways wrestlers attempt to lose weight are via dehydration, fasting, excessive vigorous exercise, laxatives, self-induced vomiting, and excessive time spent in a sauna (Gibbs et al., 2008; Opplinger et al., 2003). This is referred to as cutting weight. Oppliger et al. (2003) found the average age wrestlers began to cut weight was at 13 years old. This can be dangerous considering the nutritional needs for optimal growth are highest during this period (Atalar et al., 2009). Opplinger et al. (2003) further discussed the average weight lost during the season was 5.3 kg ± 2.8 kg, and the average weight lost per week was 2.9 kg ± 1.3 kg. If an individual were to drop a large amount of weight over an extended period of time in order to compete in a certain weight class, their BMI could decrease significantly. This would increase their risk of osteoporosis due to the lack of nutrients (1300 mg of Ca) and energy needed for optimal bone growth. Wrestlers that compete in lower weight classes are more extreme with cutting weight (Opplinger et al., 2003) which may put them at further risk for osteoporosis due their lower BMI.

It is known that increased BMI applies enough of a mechanical load on the body to cause an increase in BMD, and individuals with a higher BMI are known to have better calcium absorption and decreased parathyroid hormone secretion (Atalar et al., 2009). With that being said, what happens to BMD for individuals with lower BMI? It has been thought that the decrease in BMD of individuals with low BMI is due to less mechanical load placed on the body (Hunter et al., 2014), but Fawzy et al., (2011) states the decrease in BMD can be primarily due to a decreased level of nutrients in the bone such as calcium. This reduction occurs when there is a lack of calcium being consumed which causes an increase in parathyroid hormone that extracts calcium from the storage in the bones, causing the bones to become weak and brittle, decreasing BMD (Dawson-Hughes 2003). To conclude, low BMI is an important factor that should be taken into consideration when limiting chances of being diagnosed with osteoporosis.

More research is needed to understand the effect competing in a lower weight class has on overall bone health in wrestlers. It is true wrestling generates adequate mechanical loading via isometric contractions (Yücel & Sebiha 2016) but the concurrent practice of restricting nutritional intake can decrease bone remodeling and increase bone resorption. This can most likely be expected in adolescence where growth is most effected. More research needs to be done to understand the extended scope of how the challenges from this sport may affect BMD for young men.

Summary

Overall, research suggests weight-bearing physical activity and proper diet can lead to improvements in BMD and decrease the risk of fracture. There are multiple ways to approach improving PA and dietary intake. It is also important to maximize bone health during the prepubertal and early puberty stages because this is when a third of total BMD is accumulated (Hodges et al. 2019). Although wrestlers are known to have high levels of BMD due to training volume and intensity (Bozkurt, 2010; Długołęcka et al., 2019; Yücel & Sebiha 2016), evidence suggests wrestlers who excessively cut weight may be at risk for low BMD. Therefore, this study aims to investigate how excessive weight loss affects BMD in male high school wrestlers, as well as to determine whether there is a statistically significant difference in the proportion of wrestlers with low BMD across different weight classes.

CHAPTER III

METHODS

Participants

Existing data collected between 2005 and 2018 for 137 male high school wrestlers (14 - 18 years, *M* = 15.8 years, *SD* = 1.1 years) competed within the Tennessee Secondary School Athletic Association (TSSAA). All athletes were cutting weight and had a Dual Energy X-ray Absorptiometry (DEXA) Scan performed to determine their weight loss progression and the weight class they would qualify to enter. University Institutional Review Board approval was obtained prior to data analysis (see Appendix A).

Instrumentation

Full body scans to analyze bone density and body composition were conducted using a DEXA Hologic Discovery (Bedford, MA BONE79531-1612). The DXA Hologic Discovery has high reliability and validity for measuring bone mineral content (Shepherd et al., 2012). Participants changed into a set of medical scrubs prior to the scan and assured all metal objects were removed such as piercings and glasses. Height was measured with a Seca stadiometer (Hamburg, Germany 213 1821 009) to the nearest 10^{th} of an inch. Shoeless weight in undergarments was measured to the nearest 10^{th} of a pound. using a Seca digital scale (Hamburg, Germany 777).

Procedures

Participants arrived at the lab in a 12 hours postabsorptive (fasting) state and researchers assessed urine specific gravity and relative density using a refractometer (Bellevue, WA ATA-3749) to assure participants were not dehydrated. Following this, height and weight were assessed, and participants changed into medical scrubs. Participants were positioned on the table by an individual with a Medical X-Ray Operator-Limited certification, who ran and analyzed all scans. Scan was analyzed using the system software to generate a z-score of relative BMD.

Statistical Analysis

Descriptive statistics were calculated for height, weight, and total body segments of BMD (g/cm^2). All wrestlers were divided into weight classes based on their pre-scan weight. For children, BMD is categorized as “normal” or “low BMD,” which is a z score ≤ -2.0 (Trovato & Dietzan, 2021). A Chi-square test was conducted to determine the relationship between weight class and BMD, BMI and BMD, and BF% and BMD. Statistical significance was set at $p < .05$.

CHAPTER IV

RESULTS

Descriptive statistics are displayed in Table 1. The relationship between BMD and weight class was not significant, $\chi^2(12, N = 137) = 5.128^a$, $p = .954$. Crosstabs of the relationship between BMD and weight classes can be found in Table 2. The relationship between BMD and BMI was also not statistically significant ($r_{pb} = .103$, $n = 137$, $p = .231$). Similarly, the relationship between %BF and BMD was not statistically significant ($r_{pb} = .007$, $n = 137$, $p = .934$).

Table 1. Descriptive Statistics (*N* = 137)

	Mean ± *SD*	Skewness	Kurtosis
Height	66.5 ± 2.6	.446	-0.520
Weight	123.0 ± 17.0	2.698	11.167
BMI	19.6 ± 2.0	3.156	18.179
BF%	15.0 ± 2.5	2.822	14.143
Z-Score	0 ± 1.0	-0.091	-0.096

Note. BMI = Body mass index; BF% = Body fat percentage.

Table 2. Low and Normal BMD Among Weight Classes Crosstabs (*N* = 137)

Weight Class (lbs)	Low	Normal	Total
105	0	6	6
113	3	28	31
120	1	36	37
126	1	21	22
132	0	17	17
138	0	7	7
145	0	5	5
152	0	5	5
160	0	3	3
170	0	1	1
182	0	1	1
195	0	1	1
220	0	0	0
285	0	1	1
Total	5	132	137

Note. Low BMD is classified of having a Z score ≤ -2.0.

CHAPTER V

DISCUSSION

The purpose of this study was to examine the relationships between BMD and weight class, BMI, and BF%, respectively among high school wrestlers. The relationships were not statistically significant, indicating BMD was not related to the variables of interest. The current study is the first to the author's knowledge to assess these relationships in male high school wrestlers.

Researchers have previously evaluated the association of BMI and BMD for both males and females. As in the current study, Cherukuri et al. (2021) found no significant difference in BMD between normal and overweight BMI categories of individuals between the ages of 20 and 90 years. Earlier research also documented young adults with a BMI that fell within the normal and overweight categories were not at risk for low BMD, while those who were classified as morbidly obese were at increased risk for being diagnosed with osteoporosis (Greco et al., 2010). This could be because individuals classified as having a normal or overweight BMI usually have more muscle mass than those who have a BMI classification of underweight or obese. The current dataset only had one participant between the 170 and 285 lb weight classes (refer to Table 2), which made it difficult to assess this potential relationship within the sample.

In the current sample, five individuals out of 137 were classified as having low BMD. These participants were in the 113 (n = 31) and 126 (n = 22) lb weight classes. Roughly 3% (n = 5) of the participants within the 113 and 126 lb weight classes had a

BMI classified as being underweight (refer to Table 2). Over 65% (n = 90) of the participants ranged between the 113 and 132 lb. weight classes. Out of the five subjects that were classified as having low BMI, 60% had a BMI that classified them as being underweight. This could suggest being classified as underweight (BMI < 18.5 kg/m^2) may put adolescents at a greater risk for being diagnosed with low bone density, but further investigation is required before making a definitive conclusion.

The Centers for Disease Control and Prevention (CDC, 2022) describes that a child's BMI varies with age and is therefore categorized using normative referencing. When analyzing the relationship between BMI and BMD within the current data set, one must consider that all participants in this study were planning to drop a weight class. When attempting to drop weight, nutritional demands need to be altered to decrease caloric intake. It is known that a nutritional deficit in children and adolescents may negatively impact physical growth, cognitive development, and immune function (Norris et al., 2022). Thus, in addition to BMI nutritional intake should be analyzed in future research with wrestlers.

When assessing the relationship between BF% and BMD, there was not a statistically significant relationship, which may have been due to the lack of participants with an above average BF%. However, research has shown that BF% can be negatively related to BMD. Zhao et al. (2007) found an inverse relationship between fat mass and bone mass, suggesting that adipose tissue does not hold protective properties against osteoporosis for individuals between 19 and 45 years of age. A similar study of males between 20 and 30 years old found lean body mass to be a significant and positive independent contributor to BMD, while fat mass was negatively associated with BMD

(Sutter et al., 2019). This information suggests higher levels of BF% could be detrimental to BMD. If individuals have a high accumulation of fat mass at a young age, that may also contribute to early complications of low BMD.

Beyond consideration of body composition, research has shown individuals who weigh more have higher BMD than those with a lower weight (Atalar et al., 2009; Savvidis et al., 2018). Savvidis et al. (2018) notes that it is more beneficial to have more muscle mass, rather than fat mass, because muscle mass equally distributes a mechanical load on the human body. This is primarily due to an increased mechanical load on the skeletal frame. It is important to note similar patterns were seen within the data in this study. The wrestlers that had sufficient BMD (Z-Score $\geq$ 1.00) were in the 138 lb weight class and above, whereas over 91% of participants under the specified weight class had lower BMD (Z-Score < 1.00). This information could suggest that weighing more may be associated with higher BMD in high school wrestlers due to the mechanical loading effect on bones. Again, the lack of wrestlers falling in the heavier weight classes made this difficult to assess in the current study.

There are several limitations to the current study. First, because an existing data set was used, there were differences in the number of individuals within each weight class. Specifically, there were a limited number of wrestlers in the heavier weight classes. In future work, it would be helpful to have a more equal distribution of wrestlers across all weight classes. Secondly, the extent of participation as a wrestler was unknown for the participants. The relationship between the number of years as a wrestler and BMD would be valuable to research in the future, as longitudinally there may be a stronger relationship. Lastly, the diet of each participant was unknown. Dietary intake plays an important role in maintaining and increasing BMD during the adolescent years. This may be a confounding variable useful in future research on wrestlers.

In conclusion, osteoporosis is a major health concern that increases with age. Although current data did not document a significant relationship between BMI, BF%, and weight classes with BMD, speculations can be made that low BMI may be correlated with low BMD, but more research needs to be conducted. Education of proper diet and exercise should be given to the coaches, wrestlers, and parents. This is an imperative time for many aspects of growth for these athletes and limiting factors that may impede that growth should be the main concern. It is important to find a healthy balance between nutrition and physical activity. If one is favored or neglected, complications in weight may result, leading to a higher risk of low BMD.

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APPENDIX

Appendix A: IRB Letter of Approval

Date: 4-4-2023

IRB #: IRB-FY2023-37
Title: Effects of Weight Cutting in High School Wrestlers
Creation Date: 1-19-2023
End Date:
Status: Approved
Principal Investigator: Sebastian Ibarra
Review Board: MTSU Institutional Review Board
Sponsor:

Study History

Submission Type	Review Type	Decision
Initial	Exempt	Exempt

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