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The Effect of Magnesium Supplementation on Physical Performance of Collegiate Football Players

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THE EFFECT OF MAGNESIUM SUPPLEMENTATION ON PHYSICAL PERFORMANCE

OF COLLEGIATE FOOTBALL PLAYERS

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ABSTRACT

Mg supplementation can maximize energy stores for exercise, decrease indicators of inflammation, and increase the rate of lactate clearance. While these functions of Mg can benefit exercise capabilities, research is lacking on their effects on specific performance parameters. The purpose of this study was to determine if Mg supplementation would increase performance parameters in NCAA Division-I football players. Eighty-one participants were separated into position groups and randomly assigned to receive a daily placebo, low dose of Mg (100 mg), or high dose of Mg (200 mg). Participants completed a pre- and post-test for performance parameters that included 1RM clean, 1RM squat, 1RM bench press, vertical jump, and broad jump. Every parameter except vertical jump and broad jump had a mean increase from pre-test to post-test. In the control group, significant differences (α=0.05) were noted for the 1RM clean (8.148 $\pm$ 5.238), 1RM squat (12.370 $\pm$ 8.876), 1RM bench (9.222 $\pm$ 4.854), P4P (.840 $\pm$ .118), and total pounds (29.741 $\pm$ 16.519). In the low dose Mg group, significant differences were noted for the IRM clean (8.111 $\pm$ 5.228), 1RM squat (11.889 $\pm$ 8.894), 1RM bench (7.115 $\pm$ 4.572), and total pounds (26.852 $\pm$ 16.703). In the high dose Mg group, significant differences were noted for the 1RM clean (8.593 $\pm$ 5.235), 1RM squat (11.741 $\pm$ 7.679), 1RM bench (7.000 $\pm$ 9.695), vertical jump (.841 $\pm$ 1.861), P4P (.093 $\pm$ .113), and total pounds (27.071 $\pm$ 14.697). These differences among treatment groups are likely attributed to the effect of training. A one-way ANOVA (α=0.05) was used to determine statistical differences between and within

treatment groups, but no significant differences were noted. In conclusion, supplemented Mg had no effect on the performance parameters in this study.

DEDICATION

This thesis is dedicated to my parents, Cindy and Rich, and my fiancé, Ryan. This thesis and graduate degree would not have been completed without them.

LIST OF ABBREVIATIONS AND SYMBOLS

Mg	Magnesium
RDA	Recommended Dietary Allowance
NCAA	National Collegiate Athletic Association
NIH	National Institute of Health
NHANES	National Health and Nutrition Examination Survey
EAR	Estimated Average Requirement
GLUT-3	Glucose transporter 3
1RM	1-Repition max
P4P	Pound-for-pound
FFQ	Food frequency questionnaire
ANOVA	Analysis of variance

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Additionally, I would like to acknowledge my thesis committee, Dr. Knight, Dr. Valliant, and Dr. Joung. Their support and knowledge through the entire process was immensely appreciated. This thesis would not have turned out the way it did if it were not for their encouragement and creativity.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I: INTRODUCTION

The popularity of dietary supplements has been on the rise in recent years, especially in elite athletes. When compared to the general population, elite athletes use dietary supplements much more frequently (Knapik et al., 2016). Magnesium (Mg), specifically, can be an important mineral to supplement if its Recommended Dietary Allowance (RDA) is not fulfilled by the diet (Czaja, Lebiedzinska, Marszall, & Szefer, 2011). Mg makes itself important for exercise by functioning as a cofactor for enzymatic reactions in the body that play a role in physical performance. These include functioning as a cofactor for the enzyme creatine kinase, which maximizes energy stores in the muscle for anaerobic exercises, as well as functioning in glucose mobilization, glucose utilization, and lactate clearance (Setaro et al., 2014; Chen et al., 2009; Chen, Cheng, Pan, Hsu, & Wang, 2014).

While Mg has been shown to play a role in the capabilities of exercise, research into its effect on performance parameters of athletes is lacking. Few studies have looked at the effect of Mg supplementation in elite athletes on physical performance. Setaro et al. (2014), was one of the few studies that did so. This study found that when supplemented with Mg, the countermovement jump and countermovement jump with arm swing significantly increased in volleyball players. This study, however, found results that Mg supplementation had on a performance parameter specific to that of a volleyball player. This limited research published does not touch on the effects that Mg could have on the performance in other sports, such as football. Football players require a strength training program that enhances power, strength, and speed to reach their peak physical performance (Stodden & Galitski, 2010). Phosphocreatine

(PCr) and ATP, which is a byproduct of the enzymatic reaction involving creatine kinase, and glucose are the important energy sources for the exercises that include power, strength, and speed (Wallimann, 1994; Gastin, 2001). The anaerobic energy system, which uses ATP and PCr for energy, supports exercise requiring high power outputs, although it can only support this exercise for a limited amount of time. In turn, the aerobic energy system, which uses glucose for energy, responds and plays a role in maintaining this high intensity exercise (Gastin, 2011). Considering Mg plays a role in the function of creatine kinase and the availability of glucose, Mg can be important for these kinds of exercises. Therefore, the purpose of this research is to determine the effect of Mg supplementation on the performance parameters of NCAA Division I football players. It is hypothesized that Mg supplementation will increase performance parameters in NCAA Division I football players.

CHAPTER II: REVIEW OF LITERATURE

Dietary Supplements & Athletes

In 1994, the US Congress passed the Dietary Supplements Health and Education Act (DSHEA), defining dietary supplements as: "a product, other than tobacco, which is used in conjunction with a healthy diet and contains one or more of the following dietary ingredients: a vitamin, mineral, herb or other botanical, an amino acid, a dietary substances for use by man to supplement the diet by increasing the total daily intake, or a concentrate, metabolite, constituent, extract, or combinations of these ingredients," (Maughan, Depiesse, & Geyer, 2007). According to National Institutes of Health (NIH), supplements can help individuals obtain adequate amounts of essential nutrients that could be lacking in their diet, leading to improvements in overall health. In addition to this, some supplements have shown to be beneficial when preventing and managing some health conditions. However, the NIH does not recommend that supplements take the place of food and a healthy diet (NIH, 2011).

Still, supplement use in the United States has been increasing in popularity. According to the National Health and Nutrition Examination Survey (NHANES), supplement use from 1967-1980 was prevalent in about 35% of the population (Koplan, Annest, Layde, & Rubin, 1986). From 1988-1994, supplement use rose to encompassing 40% of the population (Balluz, Kieszak, Philen, & Mulinare, 2000). Recently, in an NHANES study from 2007-2008, it was found that approximately 50% of the US population reported using supplements (Kennedy, Luo, & Houser, 2013). As shown in these trends, supplement use is on the rise, and its popularity can be expected to further increase.

Considering that some supplements can improve athletic performance, the increase in supplement use is also seen among athletes. Maughan, Greenhaff, and Hespel (2011) asked athletes their reasons for taking supplements and found that 71% took them to aid in recovery from training, 52% took them to maintain and/or improve overall health, 46% took them to improve performance, 40% took them to prevent or treat an illness, and 29% took them to compensate for a poor diet. In NCAA Division I sports, 55% of athletes reported taking a dietary supplement two or more days/week (Ratanapratum et al., 2016). Maughan et al. (2011) found that in track athletes alone, 83% of males and 89% of females took one or more supplements. They also found that 23% and 42% of male football and soccer athletes, respectively, reported taking a vitamin supplement. Seventy-six percent of female athletes reported taking a vitamin supplement, while 54% reported taking a protein supplement. Based on these proportions, it was concluded that the use of supplements by the elite athletic population was much higher than the rest of the population (Knapik et al., 2016).

Vitamin/Mineral Supplements & Athletes

Of all the various types of supplements that can be taken by athletes, vitamins and minerals are one of the most popular choices. Bazzare et al. (1993) found that 50% of female and 51% of male athletes choose to take a vitamin or mineral supplement. More recently, a study conducted among NCAA Division I athletes found that 56.7% took one or more vitamin or mineral supplements on a regular basis, 18% took one or more on occasion, and 21.2% seldomly took a supplement. The most popular choice of supplement among this population was a multivitamin and mineral, accounting for over 70% of vitamin/mineral supplements. Second was vitamin C, followed by a multivitamin alone, B-complex vitamins, calcium, antioxidants, iron, vitamin E, and zinc (Krumbach, Ellis, & Driskell, 1999).

Although vitamins and minerals are essential to athletic performance, the decision for supplementation, however, must be made on a case by case basis. Haymes (1980), found that vitamin supplementation may not be necessary for athletes who are already getting the recommended amounts through their diet, and the extra supplementation does not increase performance. Mineral supplementation, however, may be more likely to be needed. Sodium, potassium, and Mg are three minerals whose status and function are altered by exercise. Sodium supplementation may be necessary when the athlete undergoes excessive perspiration, due to the fact that sodium is excreted through sweat (Haymes, 1980). Potassium, also lost through sweat, may be needed during times of excessive perspiration as well. The third mineral, Mg, is essential for athletes because of its role in muscle contraction and energy production (Haymes, 1980). Therefore, athletes may benefit from supplementation of these major minerals when they are not achieving the amounts they need in the diet, or are under extreme loads of training (Haymes, 1980).

Mechanisms of Magnesium

Mg is important for many functions within the body in addition to muscle contraction and energy production. Mg is especially important because it functions as a cofactor for more than 300 enzymes that control a wide range of reactions within the body. These reactions include protein synthesis, muscle and nerve function, energy production, blood glucose control, blood pressure regulation, bone development, muscle contraction, normal heart rhythm, and more (NIH, 2018). Therefore, the current RDA for Mg is over 400 mg for adult males, and over 300 mg for adult females. Mg is found in several foods, such as almonds, spinach, whole grains, legumes, seeds, brown rice, and more (NIH, 2018).

Although it would typically be present in a general multivitamin and mineral supplement, Mg can be found as a mineral supplement alone in several different forms (NIH, 2018). Recently, it has been found that a majority of Americans do not consume the Estimated Average Requirement (EAR) for their respective age groups (Moshfedg, Goldman, Ahuja, Rhodes, & LaComb, 2009). In 2001-2002, 56% of Americans met the RDA for Mg. In 2005-2006, this proportion decreased to 48% (Rosanoff, Weaver, & Rude, 2012). However, when intake from supplementation was included, Mg intakes increased to 449 mg in men and 387 mg in women, which does meet the EAR and RDA (Bailey, Fulgoni, Keast, & Dwyer, 2011).

Magnesium and Glucose

Mg is a cofactor for the enzyme creatine kinase, which is imperative for making energy to be used for exercise. This energy produced is especially important for anaerobic exercises, making Mg important for exercises that are of short duration and high-intensity (Setaro et al., 2014). To further maximize energy stores, Mg has been shown to play a role in enhancing glucose mobilization and utilization. During short duration, high intensity exercise, glucose mobilization and utilization is crucial because it is also used for energy. Glucose levels in the brain, blood, and muscle have all been shown to increase following Mg supplementation (Chen et al., 2014). Chen et al. (2009) found that when supplemented with Mg prior to participating in treadmill exercise, rats had a significant immediate increase in blood glucose. This elevated level of blood glucose lasted longer than the control group's natural increase in blood glucose from the onset of exercise. The levels of elevated glucose also remained higher than basal concentrations for an additional two hours post-exercise, which was unlike the control group. Another study reported that when supplemented with Mg prior to swimming, plasma glucose levels rose to 150-204% of the basal level. As a result of this increase in plasma glucose, the duration of exercise was improved. This effect was not seen in the group that was not supplemented with Mg (Cheng et al., 2010).

Glucose is not only important for energy during exercise, it is also the primary source of energy for the brain. The brain is responsible for regulating the coordination of motor movements, heart rate, and blood pressure during exercise. The brain is also accountable for producing substrates for energy utilization and motor functions, such as glucose transporter-3 (GLUT-3) and epinephrine. GLUT-3 is responsible for the transport of glucose to be used for energy, and its function has been shown to be enhanced with Mg supplementation. Epinephrine is responsible for increasing rates of glycogenolysis and gluconeogenesis, thereby increasing glucose levels. Consequently, this makes the supply of glucose to the brain crucial during exercise, and if brain glucose levels are depleted during exercise performance can be negatively impacted (Chen et al., 2014). When low Mg levels in the brain are reversed with Mg supplementation, there is an increased level of brain glucose and subsequent reductions in diastolic blood pressure (DBP) and systolic blood pressure (SBP). This means that there is an enhanced cardiovascular response to the exercise because of decreased blood pressure, which is an overall health benefit and may lead to improved exercise performance (Kass & Poeira, 2015).

Glucose is also important in the muscle. A high level of glucose is in the muscle means that energy stores may be maximized for exercise. Muscle glycogen stores are a major source for energy during exercise, followed by broken down glycogen stores in the liver. Chen et al. (2014) found that with Mg supplementation, glucose levels in muscle increased to 650-780% of the basal level. Consequently, this increased storage of glucose in the muscle can support exercise for a longer period of time before having to resort to liver glycogen breakdown for energy. This could potentially lead to an increase in exercise performance.

Magnesium and Exercise

In addition to its effect on glucose mobilization and utilization, Mg has been shown to have an effect on other parameters related to exercise such as inflammation, lactate clearance, and muscle function (Welch et al., 2016; Chen et al., 2014; Rude, 2012). Inflammation is a normal response to exercise and can potentially be responsible for a loss of skeletal muscle mass, muscle strength, and muscle power, resulting in decreased ability to exercise. When supplemented with Mg, it has been shown that levels of C-reactive protein, the indicator for inflammation, decreased in women (Welch et al., 2016). This decrease in inflammation can help athletes avoid the potential effects of decreased muscle mass, muscle strength, and muscle power. In turn, this can increase the capabilities of exercising.

The accumulation of lactate can also be a cause for decreased exercise ability. Lactate does this by increasing fatigue, which reduces the efficiency of exercise performance and muscle contraction. However, that Mg may be beneficial in delaying the onset of lactate accumulation (Chen et al., 2014). If the onset of lactate accumulation is delayed, exercise can be prolonged with the absence of early fatigue, and performance levels can increase. To increase lactate clearance, Mg functions as a cofactor in the enzymatic conversion of lactate to glucose. The result of this reaction is decreased lactate levels and increased blood glucose levels, which is ideal for the performance of exercise (Chen et al., 2014).

Finally, in addition to the prevention of inflammation and lactate clearance, Mg also plays a role in muscle contraction (Rude, 2012). When hypomagnesemia, or a low level of Mg, is present, neuromuscular hyperexcitability, or muscle cramps, may result while exercising (Rude, 2009). Less than optimal Mg levels can also cause muscle weakness, decreased glycogen breakdown, and increased blood pressure during exercise (Carvil & Cronin, 2010). Therefore, it is recommended that adequate levels of Mg be present prior to exercise.

Mg excretion can occur during prolonged exercise (Chen et al., 2014). This has the potential to cause hypomagnesemia and lower blood, brain, and muscle glucose levels. Further, this could cause symptoms of neuromuscular hyperexcitability, increased fatigue, lactate accumulation, and increased blood pressure (Rude, 2009; Chen et al., 2014; Carvil & Cronin, 2010). Considering some Mg is excreted as exercise is prolonged, this makes it even more imperative to have optimal Mg levels prior to the onset of exercise (Chen et al., 2014). By having optimal stores of Mg in the body, losses can be minimized and exercise can be prolonged and potentially improved upon. Therefore, this may warrant the use of Mg as a dietary supplement to increase exercise performance.

It can be concluded that either low Mg status or a Mg deficiency can have a negative effect on exercise quality. However, although low Mg status within the body can decrease performance, it has also been shown that when Mg concentrations are within normal ranges, supplementation of Mg has no extra benefits on exercise performance (Kass & Poeira, 2015). This means that an assessment of Mg status prior to exercise is important for determining if a deficiency in Mg is the underlying cause of a suboptimal performance. If low levels are reported, an intervention of Mg supplementation may be critical to reaching optimal performance levels.

Magnesium and Athletic Performance

Considering that Mg has a myriad of functions that can increase exercise capabilities, providing Mg supplements to collegiate or professional athletes may increase their athletic performance. However, research in different types of sports and their related athletic performance tests is lacking. Setaro et al. (2014) examined the relationship between Mg supplementation and the performance of elite male volleyball players. The treatment group received 350 mg of Mg over a period of four weeks and participated in several performance tests pre and post treatment. These tests included maximal oxygen uptake tests, plyometric tests, and isokinetic dynamometry tests. When athletes were supplemented with Mg, performances of countermovement jump and countermovement jump with arm swing increased. The authors suggested that the performance of these particular exercises significantly increased because they are of short duration and high intensity, or anaerobic exercises. Considering that Mg is a cofactor for creatine kinase that produces energy for these types of exercises, it can be expected that the performances would improve (Setaro et al., 2014). This theory corroborates other research that suggests that Mg maximizes energy stores in the muscle which can be used for exercise.

While this research did not include Mg supplementation, Santos et al. (2011) tested the relationship between Mg and physical performance in athletes. They used dietary assessments to determine Mg intake, and then tested performance in elite basketball, handball, and volleyball players. They found that Mg intakes were significantly lower than the RDA. Still, when Mg intake was adjusted for total energy intake, they found that certain tests of strength were directly related to the levels of Mg intake. This was true for trunk flexion, trunk rotation, handgrip maximal strength, squat jump, countermovement jump with arm swing, and some extension and flexion isokinetic strength variables. Therefore, they concluded that by increasing Mg intake, performance parameters of these certain anaerobic exercises may be improved (Santos et al., 2011).

As reported, Mg has several effects on the body due to its function as a cofactor for so many enzymatic reactions. Specifically, Mg has an effect on the ability to exercise and the quality of athletic performance. Although research is lacking on Mg supplementation and athletic performance in different sports, the current literature suggests that increased Mg status leads to an increase in performance of anaerobic exercises. The increase in blood, brain, and muscle glucose levels from Mg has a positive effect on performance. The increased lactate clearance and decreased inflammation also are factors that could lead to increased athletic performance. In future research, the effect of Mg supplementation should be studied on different athletes participating in different sports. Performance parameters relevant to different sports should be used to determine if Mg does or does not have a positive effect on athletic performance. Future research could potentially lead to the increased use of Mg supplements in the athletic population.

CHAPTER III: METHODOLOGY

Study Participants

This study was approved by the University of Mississippi Institutional Review Board, as well as by the team physician, director of nutrition services, and strength and conditioning staff for the UM football team. Participants included 81 collegiate football players all over 18 years of age. Participants were excluded from the study if they were injured, newly enrolled players, or were not participating in regular team training. Participation was voluntary and informed consent forms were given to and signed by each participant.

Materials

Treatments given to participants included either a control dose (two placebo capsules), low dose of Mg (100 mg of Mg and placebo capsule), or high dose of Mg (two 100 mg capsules of Mg). The Mg supplement came from Fuel Nutrition and was certified for sport by the National Science Foundation. The placebo used was a maltodextrin capsule provided by the Grain Processing Corporation. Participants completed both a pre- and post-test for performance parameters under the supervision of the football strength and conditioning staff for the football team in the designated weight room. This battery of tests included 1-repitition max (1RM) bench press, 1RM squat, 1RM clean, broad jump, and vertical jump. Based on these tests, other variables were calculated including pound-for-pound (P4P) lifted based on body weight for the sum of 1RM bench, squat, and clean, and total pounds from a sum of 1RM bench press, squat, and clean. Participants were also asked to complete a created food frequency questionnaire (FFQ) of high Mg-containing foods to determine their average daily Mg intake.

Treatment Groups

Participants were separated according to their position groups, which included quarterback, wide receiver, running back, tight end, offensive line, defensive line, linebacker, defensive back, and special teams. Treatment groups were then randomly assigned within position group. Treatment groups included a control group, low dose Mg group, and high dose Mg group. The supplementation was administered and recorded for 6 weeks. Throughout treatment, participants continued with their regular training regime in accordance to their football program. This included both cardiovascular activities and strength training over the duration of seven weeks, with a one week break after week five where treatment was not given. Treatment was given four days out of each week on Monday, Tuesday, Thursday, and Friday. Participants had the choice of picking up their treatment from the sports nutrition staff either before or after their scheduled training time.

Performance Parameters

The pre-test of performance parameters was completed under supervision of the strength and conditioning staff prior to the onset treatment and was already scheduled to be completed by the strength and conditioning staff on an annual basis. The results of testing were approved to be shared for purposes of this study. The subcategories for the testing included 1RM bench press, 1RM squat, 1RM clean, broad jump, and vertical jump. Based on current training loads, the strength and conditioning staff were able to predict values for each participant to work up to, and each athlete was eventually able to achieve a maximal effort test. These tests were spread out over the course of one week to allow for rest and recovery. At the end of the seven weeks, these tests were performed again, except for the 1RM bench press, 1RM squat, and 1RM clean. The values for these tests were calculated based on training loads at the time for each individual participant. If a participant did not want to complete a test, they abstained.

Average Daily Mg Intake

Average daily Mg intake was determined using the optional FFQ given to participants. This FFQ included a wide variety of foods containing Mg, and asked participants how often they consume each food in a week. Based on the responses, the average daily Mg intake was computed by dividing the average weekly Mg intake reported on the FFQ by the number of days in a week. This computed daily average could then be compared to the RDA to determine if participants usually met the RDA in the absence of a Mg supplement.

Statistical Analysis

Data were analyzed using the Statistical Package for the Social Sciences software. Differences in each performance test (range, minimum, maximum, mean $\pm$ standard deviation) were determined among all participants, regardless of treatment group. Paired sample statistics of the pre-test and post-test value for each performance parameter (mean $\pm$ standard deviation) were determined for each treatment group. A one-way analysis of variance (ANOVA) determined differences between pre- and post-test for each performance parameter between treatment groups and within treatment groups. Paired sample t-tests were also performed to determine differences between pre-test and post-test for each performance parameter for each treatment group. All tests were completed at a significance of 5% ($\alpha = 0.05$).

CHAPTER IV: RESULTS

Results of the descriptive statistics for each difference between pre-test and post-test values for the different performance parameters are shown in Table 1. Every parameter except vertical jump and broad jump had a mean increase from pre-test to post-test. Total pounds (n=81) had the largest mean increase while P4P had the smallest mean increase (n=79). Other than the 1RM clean (n=81), each performance parameter did see a possible decrease from pre-test to post-test. The difference in total pounds had the largest range of differences, while the P4P had the smallest range of differences.

Table 1
Descriptive Statistics of Differences in Performance Parameters Among Participants

Performance Test	N	Range	Minimum	Maximum	Mean
Differences in 1RM Clean	81	15.000	.000	15.000	8.284 ± 5.173
Differences in 1RM Squat	81	35.000	-5.000	30.000	12.000 ± 8.399
Differences in 1RM Bench	79	51.000	-35.000	16.000	7.798 ± 6.764
Differences in Vertical	65	8.000	-4.500	3.5000	-.246 ± 1.640
Differences in Broad	59	23.000	-14.000	9.000	-.492 ± 4.137
Differences in P4P	79	.660	-.270	.390	.076 ± .124
Differences in Total Pounds	81	76.000	-15.000	61.000	27.889 ± 15.852

In the control group, the mean value for every parameter increased from pre-test to post-test, as shown in Table 2. The largest difference between the average pre-test and post-test among this group was in total pounds (n=27), being 29.741 pounds. The smallest difference between the average pre-test and post-test in the control group was in P4P (n=20), being 0.085 pounds. In the low dose Mg group, the 1RM clean, 1RM squat, bench, P4P, and total pounds had an average increase from pre-test to post-test. The vertical jump and the broad jump had a mean decrease from pre-test to post-test. The largest positive difference between pre-test and post-test in the low dose Mg group was in total pounds (n=27), being 26.852 pounds, while the smallest difference between pre-test and post-test was in broad jump (n=19), being -0.579 inches. Similar to the low dose Mg group, the high dose Mg group saw an increase in the 1RM clean, 1RM squat, 1RM bench, P4P, and total pounds, while there was an average decrease in the vertical jump and broad jump. The largest difference in the high dose Mg group was seen in the total pounds (n=27), being 27.074 pounds. The smallest difference, showing a decrease from pre-test to post-test, was in broad jump (n=20).

Among the treatment groups, the differences from pre-test to post-test for each performance parameter were similar. The difference for the 1RM clean ranged from 8.111 to 8.592 pounds, the 1RM squat from 11.741 to 12.370 pounds, the 1RM clean from 7.000 to 9.222 pounds, the vertical jump from -0.841 to 0.228 inches, the broad jump from -1.350 to 0.450 inches, the P4P from 0.050 to 0.093 pounds, and the total pounds from 26.852 to 29.741 pounds. Figure 1 through Figure 7 show the differences between the pre-test and post-test for each performance parameter among the treatment groups. The smallest difference for the 1RM clean, P4P, and total pounds was seen in the low dose Mg group. The smallest difference for the 1RM squat, 1RM bench, vertical jump, and broad jump was seen in the high dose Mg group. The largest difference for the 1RM squat, 1RM bench, vertical jump, broad jump, P4P, and total pounds was seen in the control group. The largest difference for the 1RM clean was seen in the high dose Mg group.

Table 2

Paired Sample Statistics of Pre- and Post-Performance Parameters Among Treatment Groups

Performance Test		Control		Low Dose Mg		High Dose Mg	
		Mean	N	Mean	N	Mean	N
Pair 1	Pre-1RM Clean	293.704 ± 44.787	27	270.519 ± 34.174	27	280.741 ± 39.504	27
	Post-1RM Clean	301.852 ± 43.658	27	278.630 ± 34.616	27	289.333 ± 38.019	27
Pair 2	Pre-1RM Squat	422.704 ± 70.264	27	392.852 ± 69.249	27	422.333 ± 71.908	27
	Post-1RM Squat	435.074 ± 68.209	27	404.741 ± 69.785	27	434.074 ± 70.711	27
Pair 3	Pre-1RM Bench	301.704 ± 55.396	27	288.500 ± 51.500	26	305.808 ± 39.918	26
	Post-1RM Bench	310.926 ± 54.385	27	295.615 ± 51.379	26	312.808 ± 39.347	26
Pair 4	Pre-Vertical	31.227 ± 4.137	22	29.143 ± 4.773	21	30.705 ± 5.002	22
	Post-Vertical	31.455 ± 3.997	22	29.024 ± 4.727	21	29.864 ± 5.581	22
Pair 5	Pre-Broad	111.550 ± 10.640	20	108.263 ± 12.427	19	111.050 ±.13.755	20
	Post-Broad	112.000 ± 9.542	20	107.684 ± 12. 450	19	109.700 ± 13.819	20
Pair 6	Pre-P4P	4.397 ± .580	26	4.239 ± .827	26	4.283 ± .777	27
	Post-P4P	4.482 ± .567	26	4.289 ± .844	26	4.376 ± .758	27
Pair 7	Pre-Total Pounds	1018.111 ± 161.066	27	941.185 ± 158.514	27	997.556 ± 158.283	27
	Post-Total Pounds	1047.852 ± 157.220	27	968.037 ± 159.605	27	1024.630 ± 157.506	27

Note: Vertical = vertical jump, broad = broad jump, P4P = pound for pound.

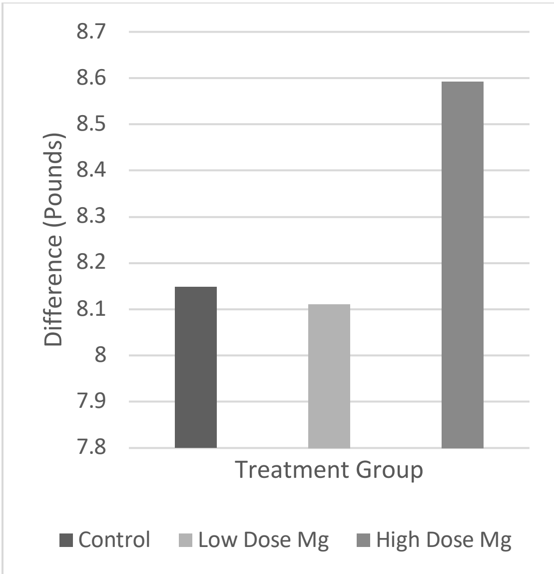

Figure 1: Difference in Pre-Test and Post-Test 1RM Clean Among Treatment Groups.

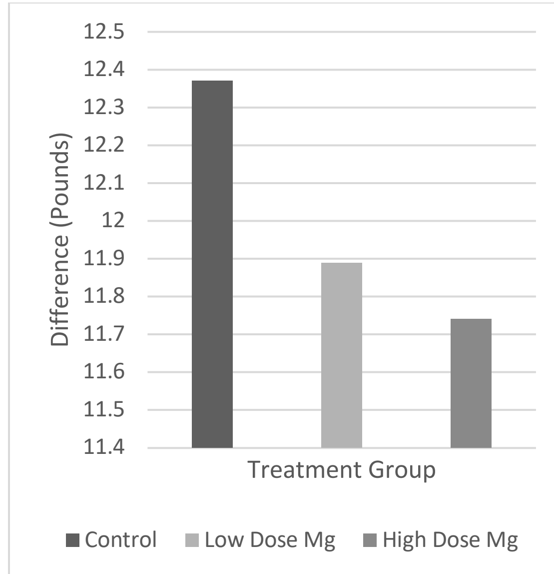

Figure 2: Difference in Pre-Test and Post-Test 1RM Squat Among Treatment Groups.

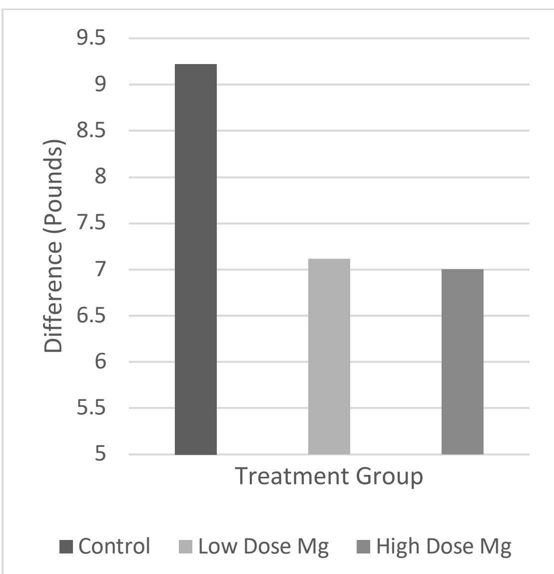

Figure 3: Difference in Pre-Test and Post-Test 1RM Bench Press Among Treatment Groups.

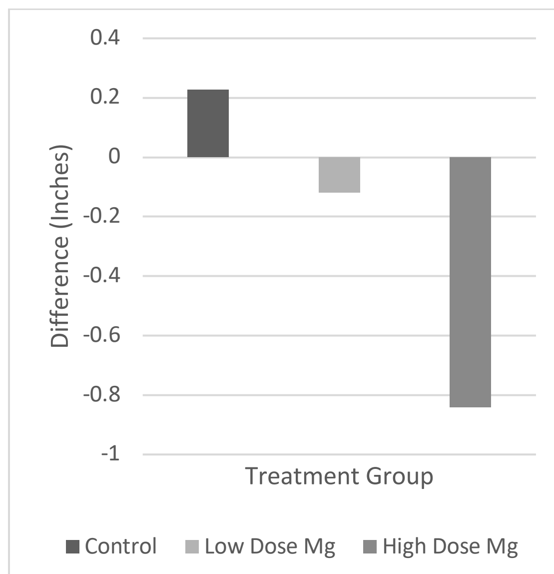

Figure 4: Difference in Pre-Test and Post-Test Vertical Jump Among Treatment Groups.

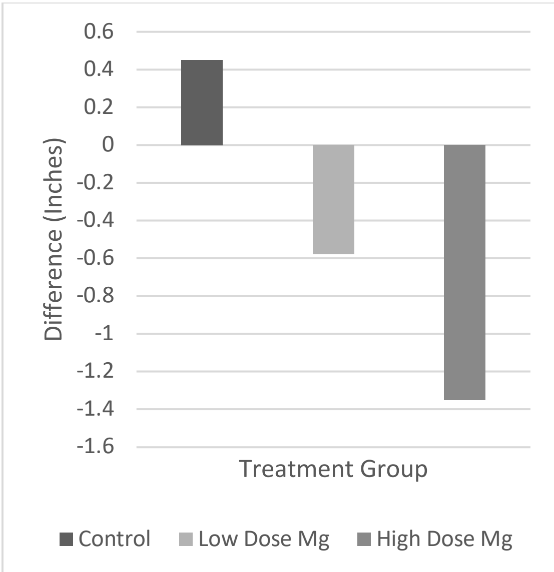

Figure 5: Difference in Pre-Test and Post-Test Broad Jump Among Treatment Groups.

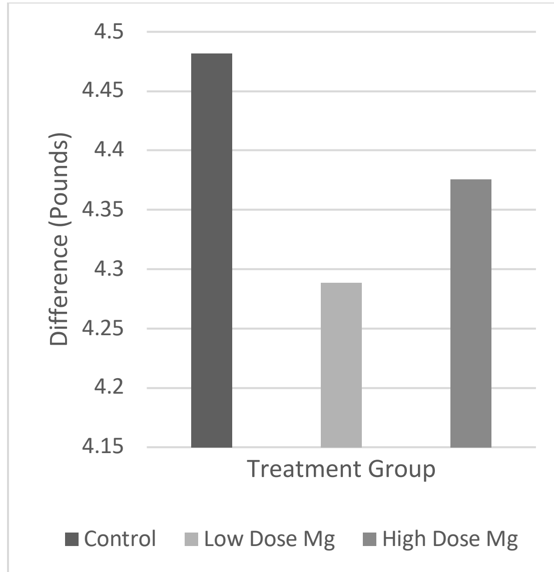

Figure 6: Difference in Pre-Test and Post-Test Pound for Pound Among Treatment Groups.

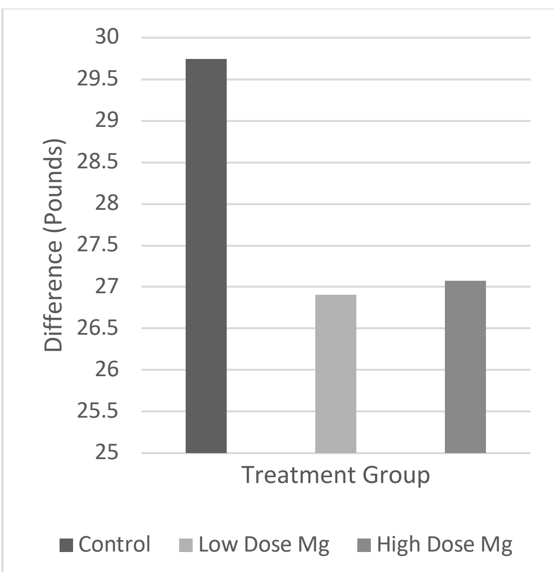

Figure 7: Difference in Pre-Test and Post-Test Total Pounds Among Treatment Groups.

To determine if there was a significant difference between the mean differences from pre-test to post-test for each performance parameter among the treatment groups, a one-way ANOVA was performed. According to Table 3, at $\alpha = 0.05$, no significant differences were noted between the differences for each performance test between or within the treatment groups.

Table 4, however, shows a paired samples t-test ($\alpha = 0.05$) for the control group, low dose Mg group, and high dose Mg group. In the control group, there was a significant difference between pre-test and post-test values for 1RM clean, 1RM squat, 1RM bench, P4P, and total pounds. In the low dose Mg group, there was a significant difference between the pre-test and post-test values for 1RM clean, 1RM squat, 1RM bench, and total pounds. The significance of the P4P increase is slightly stronger than the other significant differences noted in this treatment group. For the high dose Mg group, a significant difference is seen in the pre-test and post-test values for 1RM clean, 1RM squat, 1RM bench, vertical jump, P4P, and total pounds. The significance of the vertical jump in this treatment group represents a significant decrease in vertical jump from pre-test to post-test, according to the mean difference in inches. Each treatment group saw a significant increase from 1RM clean, 1RM squat, 1RM bench, and total pounds. Only the control group and high dose Mg group saw a significant increase in P4P. No treatment groups saw a significant increase in vertical jump nor broad jump.

Table 3
One-Way Analysis of Variance of Differences in Performance Parameters by Treatment Groups

Performance Test		Sum of Squares	df	Mean Square	F	Sig.
Differences in 1RM Clean	Between Groups	3.877	2	1.938	.071	.932
	Within Groups	2136.593	78	27.392		
	Total	2140.469	80			
Differences in 1RM Squat	Between Groups	5.852	2	2.926	.040	.960
	Within Groups	5638.148	78	72.284		
	Total	5644	80			
Differences in 1RM Bench	Between Groups	83.439	2	41.719	.910	.407
	Within Groups	3485.321	76	45.859		
	Total	3568.759	78			
Differences in Vertical	Between Groups	13.052	2	6.526	2.545	.087
	Within Groups	159.009	62	2.565		
	Total	172.062	64			
Differences in Broad	Between Groups	32.614	2	16.307	.951	.392
	Within Groups	960.132	56	17.145		
	Total	992.746	58			
Differences in P4P	Between Groups	0.027	2	0.013	.882	.418
	Within Groups	1.163	76	0.015		
	Total	1.19	78			
Differences in Total Pounds	Between Groups	139.556	2	69.778	.273	.762
	Within Groups	19964.444	78	255.954		
	Total	20104	80			

Note: Vertical = vertical jump, broad = broad jump, P4P = pound for pound.

Table 4

Paired Samples t-test of Differences in Performance Parameters Among Treatment Groups

Performance Test Pre - Post	Control				Low Dose Mg				High Dose Mg			
	Mean	t	df	Sig.	Mean	t	df	Sig.	Mean	t	df	Sig.
Pair 1: Clean	-8.148 ± 5.238	-8.083	26	.000	-8.111 ± 5.228	-8.062	26	.000	-8.593 ± 5.235	-8.529	26	.000
Pair 2: Squat	-12.370 ± 8.876	-7.242	26	.000	-11.889 ± 8.894	-6.946	26	.000	-11.741 ± 7.679	-7.945	26	.000
Pair 3: Bench	-9.222 ± 4.854	-9.872	26	.000	-7.115 ± 4.572	-7.935	25	.000	-7.000 ± 9.695	-3.681	25	.001
Pair 4: Vertical	-.227 ± 1.502	-.710	21	.486	.119 ± 1.396	.391	20	.700	.841 ± 1.861	2.120	21	.046
Pair 5: Broad	-.450 ± 4.249	-.474	19	.641	.579 ± 3.501	.721	18	.480	1.350 ± 4.568	1.322	19	.202
Pair 6: P4P	-.084 ± .118	-3.641	25	.001	-.050 ± .138	-1.836	25	.078	-.093 ± .113	-4.241	26	.000
Pair 7: Total	-29.741 ± 16.519	-9.355	26	.000	-26.852 ± 16.703	-8.354	26	.000	-27.074 ± 14.697	-9.572	26	.000

Note: Significance is 2-tailed at $\alpha = 0.05$. Clean = 1RM clean, squat = 1RM squat, bench = 1RM bench, vertical = vertical jump, broad = broad jump, P4P = pound for pound, total = total pounds.

The FFQ was used to determine the average daily Mg intake among participants. As shown in Table 5, out of the overall participants, 13 responded to the FFQ. This sample of participants made up 16% of overall participants. Among the 13 participants that responded, none of them met the RDA solely based on their dietary intake of Mg. When considering if the participants happened to be assigned 100 mg of Mg, 23% of the 13 respondents would have met the RDA. One participant who would have met the RDA with 100 mg of supplemented Mg would have only met it if they fell in the age range of 19 to 30-years-old, when it is set to 400 mg/day. If the participants happened to be assigned 200 mg of Mg, 23% of the 13 respondents would have met the RDA. Overall, 46% of participants who responded to the FFQ had the potential for meeting the RDA with supplemented Mg.

Table 5

Average Daily Intake of Mg Among Sample of Participants

Participant	Daily Intake of Mg (mg)	Daily Intake + 100 mg Mg (mg)	Daily Intake + 200 mg Mg (mg)	RDA
1	116	216	316	NOT MET
2	71	171	271	NOT MET
3	180	280	380	NOT MET
4	169	269	369	NOT MET
5	115	215	315	NOT MET
6	306	406	506	MET*
7	86	186	286	NOT MET
8	213	313	413	MET**
9	212	312	412	MET**
10	368	468	568	MET*
11	90	190	290	NOT MET
12	341	441	541	MET*
13	249	349	449	MET**

Note: *Indicates RDA met at the 100 mg and 200 mg supplemented level.
**Indicates RDA met at 200 mg supplemented level, only.

CHAPTER V: DISCUSSION

It would be expected that there would be an increase in performance parameters from pre-test to post-test for every participant over the seven-week time frame because they were undergoing conditioning and strength training. According to the minimum and maximum difference for each performance test among the participants, however, every test except 1RM clean had at least one participant decrease from pre-test to post-test. Additionally, and surprisingly, there was an average decrease among all participants on the vertical jump and broad jump. When separated into treatment groups, only the low dose Mg group and the high dose Mg group did not reveal an average increase in vertical nor broad jump. Setaro et al (2014), however, found a significant increase in the countermovement jump and countermovement jump with arm swing in the Mg supplemented group by an average of 2.5 to 3 cm. Arguably, the vertical jump can be more important to the volleyball player than it is to the NCAA football player. Therefore, the importance of training this movement may have affected the results of this performance parameter in both studies. According to Stodden and Galitski (2010), a longitudinal study of a strength and conditioning program in NCAA football found that vertical jump did not significantly increase after the first year of training for participants. This indicated a potential for adaptation to training, which may have occurred within the participants for this study as well.

It is surprising that the control group saw the largest increases in 1RM squat, 1RM bench, vertical jump, broad jump, P4P, and total pounds, while the high dose Mg only saw the largest increase in 1RM clean. However, according to Stodden and Galitski (2010), the academic year of the participants in the treatment groups could have played a role in the results. If the control group contained more freshmen, transfers, or previously injured players returning to training, this could explain why there were larger increases among this group. Stodden and Galitski (2010) state that freshmen may maximize their effort in the weight room during their first year. This statement is also supported by Smith et al (2014), when they found significant increases in 1RM bench press, 1RM squat, and 1RM clean in the group with the lower training age and training history in a NCAA Division I football program. Therefore, the increases among the treatment groups may have been a reflection of the training history of the participants in each group.

Small, but significant increases in performance parameters from pre-test to post-test among particular treatment groups were noted. The control group saw significant increases in 1RM clean, 1RM squat, 1RM bench, P4P, and total pounds. The low dose Mg group saw significant increases in 1RM clean, 1RM squat, 1RM bench, and total pounds. The high dose Mg group saw significant increases in 1RM clean, 1RM squat, 1RM bench, P4P, and total pounds. This group also saw a significant decrease in the vertical jump. There may not have been strong significant changes in performance parameters from pre-test to post-test for several reasons, including, but not limited to, the possibility of overreaching, adaptation to training methods, and potential fatigue of the participants (Moore & Fry, 2007; Hoffman et al., 2009; Häkkinen, Komi, Alén, Kauhanen, 1987; Chiu & Barnes, 2003). These substandard increases among all treatment groups are most likely attributed to training rather than the Mg supplementation.

Moore and Fry (2007) determined performance responses to off-season training in NCAA Division I-A football players. The participants underwent three different phases of training, similar to the training that the participants underwent in the current study. This study lasted a duration of 15 weeks. For phase I, players completed four weeks of resistance only training. Phase II consisted of five weeks of resistance training and morning conditioning, followed by one week of abstinence from training and one week of light conditioning, similar to the resistance training and conditioning combination the participants in the current research did. In phase III the remaining weeks were only regular football practice. Muscular strength and power determined by 1RM squat, 1RM bench, and 1RM clean, increased significantly during phase I among all participants. Muscular strength then began to decrease at the onset of phase II and throughout phase III until it reached it reached baseline levels. Therefore, the authors suggested that nonfunctional overreaching, or short-term performance decrements, may have occurred during this training regime. They also suggested that phase II, or the resistance and conditioning combined phase, should be modified to allow desired increases in performance. Although this method of training is perceived as beneficial by coaches, the authors proposed that this technique permits overreaching to occur and may not allow for variation in the program (Moore & Fry, 2007). Additionally, this program can cause training stresses on the participants, which can minimize performance gains and contribute to overreaching (Hoffman et al., 2009). Considering the similarities between the training during phase II from the study by Moore and Fry (2007) and this research, it is possibile that nonfunctional overreaching may have occurred in this study. This could explain the minor significant increases in strength among participants.

In addition to the possibility of overreaching, there is also the possibility of adaptation to strength training. When testing the strength and neural activation of muscles in elite athletes over the course of one year, Häkkinen et al. (1987) found conflicting results. Although there was a small but significant increase in performance of the clean and jerk movements over the year, there was no significant increase in the isometric strength of the leg extensors. In addition to this, depending upon the intensity of training, there either was or was not a significant difference in neural activation of the muscles. At the end of the year, Häkkinen et al. (1987) determined that there were only small increases in muscular strength. They attributed this substandard result to the intensity of training. Based on the differences in neural activation of muscles dependent upon intensity, they proposed that adaptation may have occurred and that intensity of training plays an important role in the potential for strength development. In their study, the authors proposed that the intensity of training was too low to see changes in force production. In conclusion, they suggested that elite athletes only have a limited potential for strength development (Häkkinen et al., 1987). Contingent upon their academic year or time spent training, it is possible that the athletes in the current research are at the point where they have limited potential for strength development as well. This potential difficulty to increase strength may have contributed to the lack of improvements in performance parameters from pre-test to post-test.

Finally, another possible explanation for the small improvements from pre-test to post-test could be fatigue from training and the timing of the post-tests in relation to the training schedule. This theory, called the fitness-fatigue model, states that different stresses from training results in different physiological responses to training, either being a fitness after-effect or a fatigue after-effect (Chiu & Barnes, 2003). The fitness after-effect is a positive response that leads to an improvement in performance, whereas the fatigue after-effect is a negative response that leads to a decrease in performance. The fatigue after-effect is altered by the training load, intensity, and work. Chiu and Barnes (2003) suggest that elite athletes can tolerate increases in training volume for one to three weeks before fatigue after-effects accumulate and exceed fitness after-effects, resulting in overtraining. Additionally, this increase in volume decreases the ability to recover from training. Consequently, Chiu and Barnes (2003) recommend that training volume is decreased prior to a competition to decrease fatigue after-effects and increase fitness after-effects. As previously mentioned, the participants in the current research may have been under higher training loads than they could benefit from. They did have a one-week break from training, but this was after the third week of supplementation. If overreaching did occur, the participants may have been experiencing prolonged fatigue after-effects, would could potentially explain the lack of differences from pre-test to post-test. The fitness-fatigue model also states that different types of strength training result in different after-effects. Maximal intensity training, for instance, results in the largest fatigue after-effect of all the different types of strength training. The increased after-effect then decreases the performance of maximal strength, accordingly. This implication, too, could be a reason for the substandard increases in performance parameters from pre-test to post-test in the current research.

Unlike Setaro et al. (2014), there were no significant differences between the treatment groups for performance parameters from pre-test to post-test. The reasoning for the lack of differences between treatment groups can be attributed to the possibility of overreaching, adaptation to training methods, and potential fatigue of the participants (Moore & Fry, 2007; Hoffman et al., 2009; Häkkinen et al., 1987; Chiu & Barnes, 2003). In addition to these possibilities, the chosen dosage of Mg may have also contributed to the lack of results. When comparing the amount of Mg that was given to the participants, Setaro et al. (2014) gave 350 mg of Mg while the current research provided either 100 mg or 200 mg of Mg. The Mg RDA for an 18-year-old male is 410 mg/day, and the Mg RDA for a 19 to 30-year-old male is 400 mg/day. In the Setaro et al. (2014) study, the male participants ranged from 15 to 20 years old, so the dosage of Mg almost met the RDA for both age groups. For that reason, the study was not reliant upon the participants consuming more than 50 to 60 mg of dietary Mg in addition to the supplement to reach the RDA. The current research, on the other hand, was reliant upon the participants consuming a consistent intake of 200 to 310 mg of dietary Mg to increase the total intake, including the supplement, to the level of the RDA. Out of the participants that responded to the FFQ, only 43% had the potential to reach the RDA if they were chosen to be supplemented with Mg. None of the 13 respondents actually met the RDA for Mg based solely on their dietary of intake without a supplement. This proportion of participants that would have met the RDA is similar to the proportion of Americans who meet the RDA for Mg (Rosanoff, Weaver, & Rude, 2012). As a result, compared to the dosage of Mg used in previous literature to yield significant increases in performance parameters, the current research may not have included enough supplemented Mg to see beneficial results. These results also suggest that athletes may not be consuming enough essential minerals, which could be topic for future research.

The topic of compliance with taking the supplement should also be questioned in the current research. Although treatment pick up was tracked on a daily basis, this does not guarantee that the treatments were actually consumed. Participants were not required to consume their designated treatment in the presence of a sports dietitian or member of the research team. Participants also picked up their designated treatment either before, or in most cases after, their designated weight lifting times. This is a busy time for participants, and it is a possibility that taking the treatment was forgotten or avoided on occasion.

CHAPTER VI: CONCLUSION

Supplementation of 100 mg or 200 mg of Mg did not have effect on performance parameters from pre-test to post-test among participants or between treatment groups. However, previous literature suggests that Mg can have effect on performance of athletes. The lack of significant changes in the current research may be attributed to the possibility of overreaching, adaptation to training methods, and potential fatigue of the participants. Taking into account potential lack of dietary Mg intake among the participants, the supplemented dosage of Mg chosen for the current research may have been too small for participants to reach the RDA for Mg. Therefore, further research should be conducted to determine if the dosage of Mg plays a role in its ability to increase performance parameters. Considering the lack of research on the effect of Mg supplementation in athletes, future research should also study Mg supplementation in different sports and its effect on relevant performance parameters.

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