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Effects of Magnesium Supplementation on Testosterone Levels of Athletes and Sedentary Subjects at Rest and after Exhaustion

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Abstract This study was performed to assess how 4 weeks of magnesium supplementation and exercise affect the free and total plasma testosterone levels of sportsmen practicing tae kwon do and sedentary controls at rest and after exhaustion. The testosterone levels were determined at four different periods: resting before supplementation, exhaustion before supplementation, resting after supplementation, and exhaustion after supplementation in three study groups, which are as follows: Group 1—sedentary controls supplemented with 10 mg magnesium per kilogram body weight. Group 2—tae kwon do athletes practicing 90–120 min/day supplemented with 10 mg magnesium per kilogram body weight. Group 3—tae kwon do athletes practicing 90–120 min/day receiving no magnesium supplements. The free plasma testosterone levels increased at exhaustion before and after supplementation compared to resting levels. Exercise also increased testosterone levels relative to sedentary subjects. Similar increases were observed for total testosterone. Our results show that supplementation with magnesium increases free and total testosterone values in sedentary and in athletes. The increases are higher in those who exercise than in sedentary individuals.

Keywords Exercise · Magnesium supplementation · Free and total testosterone

Introduction

Physical stress from hard exercise has a definitive effect on homeostasis. The autonomous nervous system and the hypothalamus–pituitary–adrenal axis react to protect physical integrity by restoring homeostasis [1].

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The physiologic and psychological systems work concurrently during exercise determining energy intake. Leptin and cytokines that are secreted from fatty tissues causes changes in cortisone, thyroid, and growth hormone levels [2, 3].

From a large number of studies exploring the relationship between exercise and hormones, no definite conclusion can be drawn [4–6]. Short-term strenuous exercise increased total and free testosterone levels by 12% and 13%, respectively [7]. Exercise led to increases in free and total testosterone levels in young and old subjects [8]. On the contrary, acute heavy resistance exercise reduced total and free testosterone values in 21-year-old individuals due to decreases in LH production [9]. In another study, weight lifting had no effect on testosterone levels [10].

Magnesium is an important cofactor for many enzymes, required in several biochemical events and for energy metabolism [11, 12]. It has been suggested that there is a positive correlation between magnesium levels and physical performance [13, 14]. Through high-energy diets, athletes usually receive sufficient essential minerals including magnesium. This is not the case of subjects under a diet restricted or reduced to maintain or limit their body weight, which might be a cause of insufficient magnesium intake, leading to decreases of physical performance [15, 16].

A look at the relevant literature indicates that different types of training have different effects on testosterone levels. Nevertheless, there are not many studies on the combined effects of magnesium supplementation and exercise on testosterone levels.

This study was performed to assess how 4 weeks of magnesium supplementation and exercise influence the free and total plasma testosterone levels at rest and after exhaustion in sportsmen and sedentary controls.

Materials and Methods

Subjects

Thirty healthy male subjects of ages between 18 and 22 years voluntarily participated in the study. Before the start of the research protocol, all the participants gave their consent for participation after the purpose of the study was explained to them. The participants were divided into three groups of ten subjects each, kept under distinct regimes for 4 weeks as follows:

Group 1: Sedentary subjects receiving 10 mg magnesium (as $MgSO_4$) per kilogram body weight per day.

Group 2: The subjects received the magnesium supplement while practicing tae kwon do routines for 90–120 min per day, 5 days a week.

Group 3: Subjects training as those in group 2, but without magnesium supplement.

Blood samples were drawn from all participants before and after the experimental period at rest and after exhaustion. Serum free and total testosterone values were determined by standard clinical laboratory procedures.

Exhaustion Measurements

To achieve exhaustion, the participants underwent a 20-m shuttle run test prior to blood sampling. The test was applied at the Training and Sports Academy, Selcuk University. The test starts with a slow running speed (8 km h^{-1}) in which the subject runs in a 20-m track following a signal. The subject should run to the end of the track and touch the finish line with one foot before the signal to return sounds again. The subject is allowed to continue the test if one signal is missed, but dismissed if he has difficulty in following the signal or if he or she is 3 m short of the finish line consecutively in two cycles. At this point, the running speed is increased 0.5 m/min. Each minute counts as a grade point. The result of the test is the number of accumulated points, which is taken as indicator of endurance. The duration of the test depends on the individual's ability and strength [17].

Analyses of Hormones

Blood samples (2 ml) were drawn into EDTA tubes and used to determine the testosterone levels. Free testosterone (pg/ml; lot no: 05126) was determined by means of a DSL RIA kit on gamma counter. Total testosterone (ng/dl) was determined by Acces Immunoassay system test kit and Unicel DXI 800 photoanalyser (lot no: 612500).

Statistical Analysis

The statistical analysis was performed with the SPSS statistical program. The results are expressed as means ± SD. The Kruskal–Wallis analysis of variance was used for comparison between groups, and the Mann–Whitney *U* test was applied to those with $p<0.05$.

Results

The free testosterone levels in groups 1–3 are shown on Table 1. There are no differences between these groups at rest at the beginning of supplementation (Rbs).

Exhaustion values before supplementation increased in all groups compared to rest values; there was no difference between groups (Ebs).

Comparison among groups shows that exhaustion values before supplementation were significantly higher than rest values ($p<0.05$). In the after-supplementation values, the highest levels were in group 2 Ras ($p<0.05$). The postsupplementation Ras value was higher in group 3 than in group 1. Similar increases were also observed exhaustion after supplementation (Eas) values with group 2 reaching the highest level ($p<0.05$).

When Rbs and Ras values were compared, both exercise and supplementation led to significant increases in free testosterone values ($p<0.05$).

Table 1 Free Testosterone Levels at Rest and Exhaustion, Before and After Supplementation with 10 mg/kg/day Magnesium Sulfate

	Group 1	Group 2	Group 3
Rbs	17.23±4.15***	17.78±4.45***	16.34±4.26***
Ebs	19.94±4.55**	20.84±5.25**	19.41±4.98**
Ras	17.45±4.42**,***	22.20±4.15*,****	18.80±3.91**a
Eas	21.99±6.47*a	24.65±5.27*,****	24.36±5.17*,****

Before supplementation—*Rbs* resting values, *Ebs* exhaustion values; after supplementation—*Ras* resting values, *Eas* exhaustion values

*$p<0.05$ Eas higher than Ebs; **$p<0.05$ Ebs higher than Rbs; ***$p<0.05$ Ras higher than Rbs; ****$p<0.05$ Ras and Eas in group 2 values higher than groups 1 and 3

Table 2 shows the total testosterone levels of the three study groups. No differences are seen at the start of the experiment. Total testosterone increased by exhaustion, with group 2 showing the highest increase ($p<0.05$).

The Ras values were higher in the two exercising groups than in the sedentary supplemented controls ($p<0.05$). The Eas levels of groups 2 and 3 were higher than those of group 1 ($p<0.05$). The Eas values were significantly higher than at Ebs ($p<0.05$).

Discussion

The highest level of testosterone is seen in group 2 subjects, who both exercised and received magnesium supplementation. Their Rbs and Ras are significantly different ($p<0.05$). A similar increase was found in group 3 subjects, who only trained but received no supplements.

Increases were also observed after supplementation at exhaustion, with group 2 having the highest value ($p<0.05$). Total testosterone levels also increased with exhaustion and the highest increase was seen in group 2.

Exercise substantially disrupts homeostasis by physical stress. The hypothalamus–pituitary–adrenal and gonadal axes react to this stress and thus contribute to the preservation of homeostasis and the improvement of physical fitness [18].

Magnesium is needed by the body at a certain level for good health and for maintaining physiological functions. Optimal energy metabolism and work performance depends on certain amounts of magnesium [14].

Still, findings suggesting that magnesium (Mg) enhances performance are controversial [19]. During exercise, physiological and psychological systems cooperatively determine energy need. At the same time, leptin and cytokines secreted from fat tissues affect the levels of cortisone, testosterone, thyroid, and growth hormones [2, 3]. In various studies investigating the relationship between exercise and hormones, different results were obtained [4–6].

Basal and free testosterone levels were found to be lower in cyclists than in weightlifters and a control group [20]. It was postulated that long-term cycling changes anabolic hormone levels. Another study reported that a 2-week heavy training caused a slight increase in testosterone levels [1].

In the present study, 4 weeks training and magnesium supplementation increased both free and total testosterone levels, in good agreement with the findings given above. In addition, the fact that magnesium supplements increase testosterone levels suggests the possibility that it could have a performance-enhancing effect.

Table 2 Total Testosterone Levels at Rest and Exhaustion, Before and After Supplementation with 10 mg/kg/day Magnesium Sulfate

	Group 1	Group 2	Group 3
Rbs	619.9±89.1**	624.3±92.8**	642.2±84.5**
Ebs	728.4±88.5*a	737.0±110.3*a	672.4±79.8*,**,***
Ras	631.5±95.4**b	667.3±95.2**a	698.5±83.5*,**,***
Eas	737.1±93.2*b	781.4±98.4*,***	759.8±81.55*a

*$p<0.05$ Eas higher than Ras and Ebs; **$p<0.05$ Ebs higher than Rbs; ***$p<0.05$ Groups 2 and 3 higher than group 1 at Eas and Ras

Current literature reports focus on short- and long-term testosterone response to various exercise types [2, 21]. Testosterone supplementation increased physical performance and strain by reducing fat density and increasing the amount of muscle [22]. Other studies suggest that the body's response to exercise may result from a disruption of the hypothalamus and pituitary functions in heavy, short-term exercise [23].

Similarly, severe resistance exercise reduced free and total testosterone levels as a result of a decrease in the amount of LH [24]. It was hard to find studies investigating the effects of Mg supplementation and exercise on testosterone levels. Studies on the effects of Mg supplementation on plasma levels of hormones usually focused on its effect on the response to aging or to a variety of stress factors [25, 26].

Conclusions

The effects of exercise and magnesium supplementation on free and total testosterone levels in tae kwon do athletes and sedentary subjects are reported in this study. The results show that strenuous exercise increases testosterone levels in sedentary and practicing tae kwon do athletes. The plasma testosterone levels are higher in exercising and magnesium supplemented subjects than in sedentary controls, suggesting that magnesium supplementation increases performance by increasing plasma testosterone.

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