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Original Research Article

Effects of Oral Magnesium Supplementation on Exercise-Induced Muscle Fatigue and Recovery in Healthy Adults: A Randomized Controlled Human Study

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Abstract:

Background: Exercise-induced muscle fatigue is associated with altered electrolyte balance, oxidative stress, and impaired neuromuscular function. Magnesium plays an important role in muscle physiology and energy metabolism.

Objective: To evaluate the effects of oral magnesium supplementation on muscle fatigue, recovery time, and serum lactate levels in healthy adults undergoing moderate-intensity exercise.

Methods: A randomized, double-blind, placebo-controlled human study was conducted in 60 healthy adults aged 20–35 years. Participants were randomly assigned to receive either oral magnesium citrate (400 mg/day) or placebo for 8 weeks. Exercise performance, fatigue scores, serum lactate, and recovery parameters were evaluated at baseline and post-intervention.

Results: Participants receiving magnesium supplementation showed significant improvement in muscle recovery time and reduced fatigue scores compared with placebo. Mean serum lactate levels after exercise decreased significantly in the magnesium group.

Conclusion: Magnesium supplementation may improve exercise recovery and reduce physiological fatigue in healthy adults.

Keywords: Magnesium, Exercise Physiology, Pharmacology, Human Study, Muscle Fatigue, Recovery

Introduction

Muscle fatigue is a common physiological phenomenon that occurs during prolonged or intense physical activity. It is influenced by metabolic changes, accumulation of lactate, oxidative stress, and electrolyte imbalance. Magnesium is an essential intracellular cation involved in ATP synthesis, neuromuscular conduction, and muscle contraction [1]. Previous studies suggest that magnesium supplementation may improve athletic performance and reduce muscle soreness. However, evidence regarding its role in exercise-induced fatigue in healthy adults remains limited. [2] This study aimed to investigate the pharmacological and physiological effects of oral magnesium supplementation on exercise-induced fatigue and recovery in healthy human subjects.

Materials and Methods

Study Design: Randomized, double-blind, placebo-controlled human clinical study.

Study Population: A total of 60 healthy volunteers aged 20–35 years were recruited.

Inclusion Criteria

- Healthy males and females
- BMI between 18.5–25 kg/m²
- Physically active individuals

Exclusion Criteria

- Chronic illness
- Current medication affecting muscle metabolism
- Electrolyte disorders
- Pregnancy or lactation

Ethical Approval: The study protocol was approved by the Institutional Human Ethics Committee. Written informed consent was obtained from all participants.

Intervention

Participants were randomized into:

- Group A (n = 30): Magnesium citrate 400 mg/day
- Group B (n = 30): Placebo capsule daily

Duration of treatment: 8 weeks.

Exercise Protocol: Participants performed treadmill exercise at 70% maximum heart rate for 30 minutes.

Outcome Measures

1. Fatigue Severity Scale (FSS)
2. Recovery time after exercise
3. Serum lactate concentration
4. Heart rate recovery
5. Muscle soreness score

Statistical Analysis: Data were analyzed using SPSS version 25. Results are expressed as mean ± standard deviation. Student's t-test and paired t-test were used. A p-value <0.05 was considered statistically significant.

Results

Table 1: Demographic Characteristics of Participants

Parameter	Magnesium Group (n=30)	Placebo Group (n=30)	p-value
Age (years)	26.4 ± 3.2	27.1 ± 3.5	0.42
Male/Female	16/14	15/15	0.80
BMI (kg/m²)	23.2 ± 1.8	22.9 ± 2.0	0.56
Resting Heart Rate (bpm)	74 ± 5	75 ± 6	0.48

Table 2: Comparison of Fatigue Severity Scores Before and After Intervention

Group	Baseline FSS Score	Week 8 FSS Score	p-value
Magnesium	5.8 ± 0.9	3.9 ± 0.7	<0.001
Placebo	5.7 ± 0.8	5.2 ± 0.9	0.08

Table 3: Exercise Recovery Time

Group	Baseline Recovery Time (min)	Week 8 Recovery Time (min)	p-value
Magnesium	18.6 ± 2.4	12.1 ± 1.9	<0.001
Placebo	18.2 ± 2.1	17.3 ± 2.2	0.11

Table 4: Post-Exercise Serum Lactate Concentration

Group	Baseline (mmol/L)	Week 8 (mmol/L)	p-value
Magnesium	6.8 ± 1.1	4.9 ± 0.8	<0.001
Placebo	6.7 ± 1.0	6.3 ± 0.9	0.14

Table 5: Heart Rate Recovery at 5 Minutes Post-Exercise

Group	Baseline (bpm)	Week 8 (bpm)	p-value
Magnesium	102 ± 8	89 ± 6	<0.001
Placebo	101 ± 7	98 ± 7	0.09

Discussion

The present study demonstrated that oral magnesium supplementation significantly improved exercise recovery parameters and reduced fatigue severity among healthy adults undergoing moderate-intensity physical activity. Participants receiving magnesium supplementation exhibited lower Fatigue Severity Scale scores, reduced post-exercise serum lactate concentrations, and improved heart rate recovery compared with the placebo group.

Magnesium is a critical cofactor in more than 300 enzymatic reactions involved in ATP production, neuromuscular transmission, oxidative phosphorylation, and protein synthesis. Adequate intracellular magnesium concentrations are essential for maintaining skeletal muscle contraction-relaxation cycles and cellular energy metabolism. During prolonged exercise, magnesium loss through sweat and urinary excretion may contribute to impaired muscle performance and delayed recovery.

The reduction in fatigue severity observed in the present study may be explained by enhanced mitochondrial energy production and improved neuromuscular efficiency associated with magnesium supplementation. Previous studies have demonstrated that magnesium plays an important role in regulating glucose utilization and ATP synthesis during exercise stress. Volpe reported that magnesium deficiency can impair exercise performance by reducing oxygen uptake efficiency and increasing energy expenditure during physical activity [3,6].

In the present study, serum lactate levels decreased significantly in the magnesium-treated group after 8 weeks of supplementation. Elevated serum lactate is a physiological marker of anaerobic metabolism and muscular fatigue. Lower lactate accumulation following exercise suggests improved aerobic metabolic efficiency and delayed onset of muscular exhaustion. Similar findings were reported by Cinar et al., who observed improved physical perfor-

mance and reduced exercise stress markers after magnesium supplementation in athletes [4,5,8].

Improved heart rate recovery observed in the magnesium group may indicate enhanced autonomic regulation and cardiovascular adaptation. Magnesium contributes to normal cardiac electrophysiology and vascular smooth muscle relaxation. Faster post-exercise heart rate recovery is associated with improved parasympathetic reactivation and cardiovascular fitness.

Muscle soreness and delayed recovery following exercise are often associated with oxidative stress and inflammatory responses. Magnesium possesses indirect antioxidant and anti-inflammatory properties through stabilization of cellular membranes and regulation of calcium influx. Gröber et al. suggested that magnesium supplementation may reduce inflammatory cytokine activity and oxidative damage during physiological stress conditions [9].

The findings of the current study are also supported by the physiological review conducted by de Baaij et al., which emphasized the importance of magnesium in maintaining muscular and neurological function [10]. Magnesium deficiency has been associated with muscle cramps, weakness, fatigue, and impaired exercise tolerance.

Although the present findings suggest beneficial effects of magnesium supplementation, several limitations should be considered. The study included a relatively small sample size and short intervention duration. Additionally, dietary magnesium intake and long-term follow-up were not evaluated. Future multicenter clinical studies with larger populations and biochemical assessment of intracellular magnesium levels are required to establish stronger clinical evidence.

Overall, the present study supports the potential role of magnesium supplementation as an adjunct nutritional pharmacological intervention for improving exercise recovery and reducing fatigue in healthy adults.

Conclusion

Oral magnesium supplementation may improve exercise recovery, reduce fatigue severity, and lower serum lactate accumulation in healthy adults. Larger multicenter human trials are required to validate these findings.

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