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Correlation of Magnesium and Calcium Intake with Cardiorespiratory Endurance in Adolescent Athletes

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ABSTRACT

Adequate micronutrient intake plays a critical role in supporting physiological adaptation and performance in adolescent athletes who undergo intensive training during periods of rapid growth. This study aimed to analyze the correlation between magnesium and calcium intake and cardiorespiratory endurance among adolescent basketball athletes. A total of 25 athletes aged 13–18 years participated in this observational cross-sectional study. Dietary magnesium and calcium intake were assessed using a validated Semi-Quantitative Food Frequency Questionnaire (SQ-FFQ), reflecting habitual intake over one month. Cardiorespiratory endurance was evaluated through estimated VO_2 Max obtained from the standardized Multistage Fitness Test (bleep test). The results showed that the mean intake of both magnesium and calcium among participants was within recommended adequacy levels. Correlation analysis revealed a strong and statistically significant positive relationship between magnesium intake and VO_2 Max ($r = 0.72$; $p < 0.05$), as well as between calcium intake and VO_2 Max ($r = 0.75$; $p < 0.05$). These findings indicate that higher mineral intake is associated with better aerobic capacity in adolescent athletes. From a physiological perspective, magnesium plays a key role in ATP synthesis, neuromuscular transmission, and muscle relaxation, while calcium is essential for excitation–contraction coupling, cardiovascular regulation, and metabolic stability during prolonged high-intensity exercise. In conclusion, adequate intake of magnesium and calcium is significantly associated with improved cardiorespiratory endurance in adolescent basketball athletes. These findings highlight the importance of integrating mineral adequacy into athlete development and nutrition education programs, particularly during adolescence, to optimize aerobic performance and support long-term athletic development.

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INTRODUCTION

The background of this study is grounded in the importance of mineral adequacy among adolescent athletes, particularly magnesium and calcium, which play central roles in muscular function, cardiovascular performance, and energy metabolism during intensive physical activity. Adolescent basketball players are in a period of growth and

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physiological adaptation that requires optimal nutritional intake. Prolonged physical activity such as basketball increases the body's mineral demands, particularly because magnesium is involved in more than 300 enzymatic reactions related to ATP production, neuromuscular transmission, and muscle relaxation. Magnesium deficiency is frequently associated with increased muscle fatigue, reduced contractile ability, and decreased aerobic performance. At the same time, calcium is a key component in muscle contraction signaling, and it also plays crucial roles in cardiovascular function, blood coagulation, and bone density maintenance an essential aspect during adolescence when active growth occurs (Abreu, et. al. 2023).

In competitive sports such as basketball, the ability to maintain high-intensity performance over a prolonged duration is strongly influenced by cardiorespiratory endurance, which is commonly assessed using tests such as the Multistage Fitness Test (bleep test) to estimate VO_2 Max. VO_2 Max represents the maximum capacity of the body to utilize oxygen during intensive exercise and is widely recognized as one of the best indicators of aerobic fitness. Numerous studies have demonstrated that nutritional quality, including mineral intake, significantly affects athletic performance. Athletes with adequate mineral consumption tend to exhibit better muscle function, faster recovery, and more optimal energy production during training and competition (Amawi, et.al. 2024).

The data obtained in this study demonstrate a consistent pattern between adequate magnesium and calcium intake and improved VO_2 Max among adolescent basketball players. The strong and statistically significant correlation between magnesium intake and cardiorespiratory endurance, as well as between calcium intake and cardiorespiratory endurance, indicates that sufficient mineral consumption contributes positively to aerobic performance. Additionally, the close relationship between magnesium and calcium intake suggests that athletes with good dietary habits tend to meet both mineral needs simultaneously (Armento, et. al. 2023). This condition may reflect better dietary discipline, supportive coaching and nutritional environments, or the implementation of effective nutrition education programs. These findings are particularly important considering that many adolescent athletes undergo intensive training schedules yet often lack sufficient attention to daily micronutrient requirements. Imbalances between training load and nutritional intake may lead to reduced performance, increased injury risk, or suboptimal physiological adaptation to exercise (Abrams, et. al. 2021). Therefore, this study reinforces the urgency for coaches, sports nutritionists, schools, and athlete development institutions to ensure mineral adequacy as part of the daily dietary planning for young athletes. Proper nutrition education support is essential to prevent deficiencies, maximize muscle work capacity, and enhance cardiorespiratory endurance, which ultimately improves competitive performance.

In conclusion, this research highlights that magnesium and calcium intake is not only associated with basic physiological needs but also has a direct correlation with specific aspects of physical performance relevant to high-intensity sports such as

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basketball. This understanding is expected to serve as a basis for developing more targeted athlete development programs grounded in sports nutrition science and to support further research on the effectiveness of nutritional interventions in enhancing the performance of adolescent athletes.

METHODS

This study used an observational cross-sectional design to analyze the relationship between magnesium and calcium intake and cardiorespiratory endurance in adolescent athletes. This design was chosen because it is effective for evaluating the relationship between nutritional variables and physical performance in a non-interventional sports field context and is widely used in contemporary sports nutrition studies.

The study subjects consisted of 25 adolescent basketball athletes aged 13–18 years, recruited using purposive sampling from several sports clubs and educational institutions. Inclusion criteria included: (1) active athletes who participated in regular training at least three times per week, (2) no history of chronic disease or mineral metabolism disorders, and (3) ability to complete all measurement procedures. Exclusion criteria included acute injury within the past month, consumption of high-dose mineral supplements within the past three months, and inability to complete the fitness test. All study procedures were approved by the institutional ethics committee, and informed consent was obtained from participants and parents/guardians for participants under 18 years of age.

Data collection was conducted over a standardized measurement period. Magnesium and calcium intakes were assessed using a Semi-Quantitative Food Frequency Questionnaire (SQ-FFQ) adapted and pilot-tested in a population of adolescent athletes. This instrument includes approximately 70–100 food and beverage items representing local consumption patterns and primary sources of magnesium and calcium. A one-month reference period was used to reflect habitual intake while minimizing recall bias. Consumption frequencies were converted to estimated daily intakes by calculating standardized portion sizes using portion photographs, visual aids, and guidebooks. Mineral content values were obtained from the latest national food composition tables and validated regional food databases.

Cardiorespiratory endurance was measured using the Multistage Fitness Test (bleep test) according to a standard protocol. Participants ran a 20-meter round-trip run at a progressively increasing speed until reaching maximal exhaustion. The level and endpoint reached were recorded to estimate VO_2 max using the Léger formula, which has been widely validated in adolescent athletes. All tests were conducted on a flat surface with a controlled warm-up and supervision to ensure safety.

Anthropometric data (height and weight) were measured using calibrated equipment to support subject characterization. Statistical analyses were performed using standard statistical software. Normality was tested using the Shapiro–Wilk test. The relationship between magnesium and calcium intake and VO_2max was analyzed using Pearson or Spearman correlation tests, according to the data distribution, with a

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significance level of $\alpha = 0.05$. To evaluate the relative contribution of these two minerals to VO_2max, linear regression analyses were performed, controlling for confounding variables such as age, sex, and exercise duration.

To ensure data quality, this study employed enumerator training, instrument pilot testing, and double-checking procedures. Although the SQ-FFQ is effective for assessing patterns and relative adequacy of mineral intake, limitations such as potential recall bias remain important in interpreting the results. Therefore, the findings of this study are recommended as a basis for further studies with longitudinal designs or the use of biomarkers of mineral status.

RESULTS AND DISCUSSION

This study involved 25 adolescent basketball athletes whose magnesium and calcium intake were assessed using a Semi-Quantitative Food Frequency Questionnaire (SQ-FFQ), while cardiorespiratory endurance was evaluated through VO_2 Max measurement using the bleep test. The findings showed that the average magnesium intake of participants was categorized as adequate, with a mean value of 351.2 ± 18.5 mg/day. Meanwhile, the mean calcium intake was 1125.6 ± 78.4 mg/day. Cardiorespiratory endurance represented by VO_2 Max demonstrated a mean value of 45.2 ± 4.1 ml/kg/min, indicating a good fitness level for the adolescent basketball athlete population. Pearson correlation analysis revealed a significant association between magnesium intake and cardiorespiratory endurance, with a correlation coefficient of $r = 0.72$ ($p < 0.05$). This suggests that higher magnesium intake is associated with better cardiorespiratory performance. Magnesium plays a critical role in muscle contraction regulation, nerve impulse transmission, and energy production through enzymatic activation in ATP metabolism, thereby highlighting its importance in supporting athletic performance, particularly in activities requiring prolonged endurance capacity.

In addition to magnesium, calcium also demonstrated a significant positive correlation with VO_2 Max, with a correlation coefficient of $r = 0.75$ ($p < 0.05$). Calcium is an essential mineral involved in excitation–contraction coupling in both skeletal and cardiac muscle cells. Adequate calcium availability contributes to energy utilization efficiency and effective contraction mechanisms during high-intensity activity. Among basketball athletes engaged in routine and intensive training, calcium requirements are relatively higher to maintain optimal neuromuscular function and prevent performance decline due to muscle fatigue (Wang, et. al. 2025). The strong association between both mineral intakes and VO_2 Max indicates that macro-mineral nutritional status plays a substantial role in cardiorespiratory performance among adolescent athletes. These findings are consistent with previous studies reporting that athletes with sufficient mineral intake generally exhibit better aerobic capacity compared to those with inadequate intake. Moreover, the adolescent age context adds significance, as this developmental period is characterized by increased metabolic demand due to musculoskeletal growth and physiological adaptation during intensive training (Capra, et. al. 2024).

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Table 1.
Correlation Number of Each Variables

Variable	Magnesium (mg/day)	Kalsium (mg/day)	VO_2 Max (ml/kg/minutes)
Magnesium (mg/day)	1.00	0.78	0.72
Kalsium (mg/day)	0.78	1.00	0.75
VO_2 Max (ml/kg/minutes)	0.72	0.75	1.00

Based on the correlation analysis presented in the table above, it is evident that magnesium and calcium intake show a significant positive association with cardiorespiratory endurance performance, as represented by VO_2 Max values. The correlation coefficient of 0.72 between magnesium intake and VO_2 Max indicates that higher magnesium intake is associated with improved aerobic capacity. This relationship may be attributed to the role of magnesium as a cofactor in ATP synthesis and neuromuscular stabilization, which is crucial during high-intensity activities such as basketball. Similarly, calcium demonstrated a strong correlation with VO_2 Max ($r = 0.75$), indicating its essential contribution to muscle contraction processes and nerve impulse transmission, thereby influencing movement efficiency and endurance capacity. The strong relationship between the two minerals is further reflected in the correlation coefficient of 0.78, suggesting that athletes with higher magnesium intake tend to have adequate calcium consumption as well. Overall, these findings indicate that sufficient magnesium and calcium intake plays a key role in enhancing cardiorespiratory performance and provides an important basis for nutritional recommendations for adolescent athletes to support optimal physical performance.

Overall, these results highlight the importance of ensuring adequate magnesium and calcium intake in the dietary patterns of adolescent basketball athletes as part of a sports nutrition strategy. Adequate intake of these minerals not only supports muscle function and energy metabolism but also contributes to improved cardiorespiratory performance reflected by increased VO_2 Max. Therefore, nutrition education emphasizing mineral adequacy should be integrated into athlete development programs to enhance training performance and sustain long-term athletic achievement (Vicente, et. al. 2023). From a biochemical perspective, the significant association between magnesium and calcium intake and cardiorespiratory endurance can be explained through energy metabolism mechanisms and muscle contraction physiology. Magnesium serves as an essential cofactor in more than 300 enzymatic reactions, including oxidative phosphorylation within the Krebs cycle and the electron transport chain in mitochondria (Hunt, et. al. 2021). During high-intensity exercise such as the bleep test, ATP demand increases sharply to support repeated muscle contractions. Magnesium forms a complex with ATP (Mg-ATP), stabilizing its molecular structure, and without sufficient magnesium, ATP cannot be effectively utilized by muscle cells to generate efficient contractions. Magnesium deficiency may impair aerobic energy production and promote anaerobic metabolite accumulation, such as hydrogen ions and lactic acid, ultimately accelerating muscle fatigue (Domínguez, et. al. 2024).

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Beyond its role in energy metabolism, magnesium also regulates intracellular calcium homeostasis. It controls calcium channels on the plasma membrane and sarcoplasmic reticulum, influencing calcium release during excitation–contraction coupling. Imbalance in magnesium levels may lead to unstable calcium flux, triggering muscle cramps, reduced contraction efficiency, and impaired recovery following intense physical exertion (Hariri & Rekhis, 2025). Calcium itself plays a pivotal role in the excitation–contraction mechanism of muscle fibers. Upon neuromuscular stimulation, calcium ions enter the cytosol and bind to troponin C, inducing conformational changes in tropomyosin that expose actin-binding sites for myosin attachment. This sliding filament mechanism drives muscle contraction. In aerobic energy systems associated with cardiorespiratory fitness, sustained contraction over an extended period is required, and sufficient calcium availability ensures repeated actin–myosin cycling occurs efficiently. Consequently, athletes with adequate calcium intake are better able to maintain high muscle workload without performance decline (Hernández, et. al. 2024).

Furthermore, calcium also contributes biochemically to energy metabolism through activation of key aerobic enzymes, including isocitrate dehydrogenase in the Krebs cycle. The activity of this enzyme increases with elevated intracellular calcium during muscle contraction, accelerating decarboxylation processes and enhancing NADH production, which is later oxidized in the electron transport chain for ATP synthesis (Jakše, et. al. 2021). This mechanism explains the association between adequate calcium intake and greater capacity to sustain aerobic energy production during maximal activity, such as the bleep test. Both minerals also act synergistically to support cell membrane stability, nerve impulse transmission, and myocardial function. In athletes with sufficient magnesium and calcium levels, neurotransmitter release, cardiac muscle contractility, rhythm stability, and oxygen distribution are maintained optimally, contributing directly to improved VO_2 Max (Newbury, et. al. 2022). This supports superior cardiorespiratory performance, as the heart pumps blood more efficiently, skeletal muscles utilize oxygen more effectively, and energy metabolism proceeds at high rates without metabolic failure. Thus, from a biochemical standpoint, the significant association between magnesium and calcium intake and VO_2 Max is not merely statistical, but reflects the integrated metabolic and neuromuscular mechanisms underlying adolescent athletic performance (Pan, et. al. 2020). These findings strengthen the notion that micronutrient adequacy is not only essential for health but is also fundamental for optimizing training performance through enhanced energy metabolism efficiency, muscle contraction, and physiological as well as biochemical cardiorespiratory endurance (Tarsitano, et. al. 2024).

CONCLUSION

This study demonstrates that magnesium and calcium intake have a significant positive association with cardiorespiratory endurance among 25 adolescent basketball athletes, as indicated by VO_2 Max measurements using the bleep test. Athletes with

higher intake of both minerals tended to exhibit better aerobic capacity, reflecting enhanced energy metabolism efficiency and optimal muscle contraction function. These findings reinforce the premise that adequate intake of macro-mineral nutrients plays an essential role in improving sports performance through physiological and biochemical mechanisms, particularly in young athletes who are in a phase of bodily adaptation and developmental growth. Based on these results, coaches and sports educators are advised to place greater emphasis on fulfilling nutritional needs, especially magnesium and calcium, through nutrition education, daily menu planning, and integration into training programs for adolescent athletes. Further research with a broader design and additional analyses, such as long-term intervention studies, is recommended to strengthen understanding of the influence of mineral intake on cardiorespiratory performance and metabolic adaptation mechanisms in young athletes.

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