Analysis of Dietary Micronutrient Intake of NCAA Track and Field Athletes

Original Research

Haley Melton [1], Corbit Franks [1,3,4], Tyler Myers [1,2,3], Samantha Kostelnik [5], David Joung [2] and Melinda W Valliant [1,2]

[1]*Center for Health & Sports Performance, University of Mississippi, University, MS/United States of America*
[2]*Department of Nutrition & Hospitality Management, University of Mississippi, University, MS/United States of America*
[3]*Human Movement & High-Performance Lab, University of Mississippi, University, MS/United States of America*
[4]*Department of Health, Exercise Science & Recreation Management, University of Mississippi, University, MS/United States of America*
[5]*Pennsylvania State University Athletics, State College, PA/United States of America*

Open Access

Published: August 8, 2025

Journal of Exercise and Nutrition: *2025, Volume 8 (Issue 1): 16*

ISSN: 2640-2572

Abstract

Introduction: Micronutrients are critical to optimal physiological function of the human body's overall health and homeostasis. An athlete's performance and recovery may be inhibited by micronutrient deficiencies[1]. This study analyzed the micronutrient consumption of National Collegiate Athletic Association (NCAA) Division I Collegiate Track and Field athletes.

Methods: Thirty-seven track and field athletes, 15 females and 22 males participated. Multiple 24-hr recalls were collected, including weekdays and weekends, and analyzed using Nutrition Data System for Research (NDSR) to obtain dietary micronutrient intakes. Average intakes were compared to the Recommended Dietary Allowance (RDA) for each micronutrient. Pearson Chi Squared tests were used to assess correlations amongst the participant characteristics, gender, age, race, track event group, and residence.

Results: Many participants under-consumed micronutrients, most commonly magnesium, calcium, and vitamin D. Significant correlations were found between gender and iron intake, race and magnesium intake, and residence and calcium intake. Results indicated a significant relationship between gender and dietary iron intake ($p < 0.001$), residence and calcium consumption ($p < .05$), and the race and magnesium intake ($p < .05$). Males were more likely to meet the iron RDA, and Caucasians had higher magnesium intake than African Americans. Those living on-campus were more likely to meet calcium requirements than off-campus.

Conclusions: These findings highlight the need for dietary education and the importance of assessing micronutrient intake. While the impact of these nutrients on athletic performance justifies such efforts, their broader implications for overall health reinforce the necessity of thorough dietary analysis. Athletic programs should evaluate micronutrient intake alongside total caloric and macronutrient consumption.

Key Words: Athlete, Nutrition, Performance

Corresponding author: Melinda Valliant, valliant@olemiss.edu

Introduction

Micronutrients play a vital role in a human's overall health and well-being. Both vitamins and minerals assist in daily physiological functions such as digestion, metabolism, cellular growth, and reproduction[1,2]. Micronutrients may only be needed in small amounts compared to macronutrients, but serious health and performance implications can occur when intake is insufficient, and a deficiency occurs[3]. Athletic performance and prolonged exercise may create immunosuppressant events in individual athletes, leading to increases decreases of the immune system and increased likelihood of fatigue and illness[4]. The use of nutrients to restore energy stores may also be useful in preventing illnesses such as upper respiratory infections. The immune system's ability to properly fight infection or clear viruses is dependent upon an adequate supply nutrients[5]. Many vitamins and minerals are considered essential because they must be obtained from the diet; therefore, it is crucial for individuals to obtain a well-balanced diet[1].

A variety of foods and beverages in the diet provide the body with various nutrients, but there is not one singular item that can provide the body with everything it requires to function properly. Instead, we must incorporate a variety of foods to ensure the body is able to get all the macronutrients, vitamins, and minerals it requires to carry out its daily physiological functions[1,2,6,7]. Eliminating, or even restricting any of the food groups from usual intake increases an individual's risk of developing detrimental health effects resulting from nutrient deficiencies[1,6-10]. Along with health effects, athletes could see negative impacts on their performance when trying to compete with nutrient deficiencies.

Consuming a balanced diet to include all nutrients is easier said than done for many. Difficulties arise when an individual lacks the knowledge of how to ensure they are obtaining all the essential nutrients. Aside from adults who are pursuing a career in a nutrition-related field, many people in the United States have limited nutrition knowledge, which can negatively impact their dietary selections[3,11-13]. Although nutrition knowledge does not always translate to behavior, it is difficult to expect adequate dietary intakes from individuals who do not have the knowledge related to the various food groups, much less the importance of each vitamin and mineral.

The inability to obtain adequate nutrients because of access is another barrier. Food insecurity, insufficient amounts or quality of food to support an individual's needs, is a prevalent issue on many college campuses [14,15]. A study concluded 35 to 42% of college students struggle with food insecurity [14]. Being a student-athlete does not guarantee the individual is food secure. Division I is the highest level of collegiate athletics, yet despite the affluence of athletics programs at these institutions, athletes still have a difficult time obtaining adequate amounts of food[15,16].

Current research indicates under consuming the recommended intakes for various micronutrients is prevalent in approximately 31% of the U.S. population[2,7,8,17]. Track and field athletes in particular present risks of under consumption because of their lack of nutrition knowledge and increased risk of food insecurity due to the limited number of student-athletes that receive scholarships [18]. Collegiate track and field programs have upwards of 100 student-athletes on their rosters but are only provided a minimal number of scholarships to divide among those athletes. Scholarships are awarded using an equivalency system, and it is rare for an individual to receive anything other than a partial scholarship, requiring the student-athlete to contribute funds to the cost of attending a college or university [18]. Increasing nutrition knowledge and self-regulation may decrease the likelihood of under consumption of calories and micronutrients in this population[19]. Mancone et al.[19] show that increasing food literacy, food label interpretation skills and cooking skills may positively affect overall nutritional intake, which conversely may aid this population in increasing micronutrient intake.

A gap in the literature fails to include the prevalence of NCAA track and field athletes at risk of under consuming vital nutrients. The purpose of this study was to assess NCAA track and field student athlete's consumption of micronutrients. Vitamin C, vitamin D, iron, calcium, and magnesium were selected for this study primarily because of the negative performance effects associated with under consumption and prevalence of deficiency depicted in current literature.

Prevalence and Symptomology of Deficiencies

According to the existing literature, prolonged inadequate intake of specific micronutrients may lead to deficiencies and decreases in athletic performance and overall health and well-being[1]. To prevent deficiencies from occurring it is recommended that individuals aim to consume recommended amounts of each nutrient daily. These values have been determined by the Food and Nutrition Board of the Institute of Medicine and are known as the Recommended Daily Average (RDA) and Estimated Average Requirement (EAR)[20]. Symptoms may occur in individuals who are under consuming the recommended intakes for micronutrients, even if they are not clinically diagnosed as deficient[3]. These symptoms may include irritability, fatigue, soreness, impaired immune function and irregular heart rhythms[2].

Current research suggests the best way to prevent micronutrient deficiencies, even on a sub-clinical level, is through consistent intake of a well-balanced diet that is suitable for the individual's caloric and macronutrient needs[9]. Unfortunately, studies have found that a low proportion of people in the United States consume a diet that provides recommended amounts of all essential vitamins and minerals[2,7]. Adequate levels of micronutrients are crucial for proper health, but up to one-third of the population are at risk of micronutrient deficiencies, sometimes because of under consumption through the diet[2]. One study concluded that most of the U.S. population under-consumes many essential micronutrients, including vitamin D, vitamin C, calcium, and iron when compared to the EAR[2].

According to McClung et al., women are at a higher risk of micronutrient deficiencies than men, who are often consuming macronutrients and micronutrients at suboptimal amounts[8,9]. The most common nutrient deficiencies in females were vitamin D, calcium, and iron[17]. All females are predisposed to a higher risk of deficiencies, stemming from a generalization of inadequate energy availability or under consuming macronutrients[2,6]. Specifically, it seems women are more likely to have iron and vitamin D deficiencies compared to males[2]. Men are not exempt from micronutrient deficiencies, however. One study found a higher prevalence of vitamin C deficiency in males (8.7%) compared to females[2].

Athletes are also susceptible to vitamin and mineral deficiencies. In fact, Heffernan et al. concluded that up to 60% of athletes may be deficient in some micronutrients[7]. The literature currently does not provide adequate evidence to conclude that sufficient levels of micronutrients, or elevated intakes of specific micronutrients, can positively impact athletic performance[7]. However, it can be concluded that deficient or insufficient levels of vitamins and minerals can cause detrimental effects to performance because of the symptoms associated with the deficiencies [2,3].

The literature confirms the best way to avoid micronutrient deficiencies is to consume adequate calories to match an individual's energy expenditure[1,6,8]. This can be achieved when consuming from a wide variety of foods that supports their health status and promotes optimal performance in athletes[9]. Unfortunately, the primary cause of micronutrient deficiencies is related to under consumption of total energy, either unintentionally associated with a lack of knowledge, or in a restrictive manner[6,8-10,17]. People who are not consistently obtaining adequate calories and macronutrients have the potential to develop micronutrient deficiencies [9]. An athlete may be at a further disadvantage because of their higher energy demands but it is currently unknown if athlete's have a higher demand for micronutrients [1,3,6-8].

Under consumption of vitamins and minerals for an extended period can result in insufficient or deficient levels of micronutrients, causing serious health and performance implications for the individual, such as fatigue, lack of concentration, or delayed muscle recovery[2,7]. In the early stages of low levels some symptoms may be difficult to associate with micronutrient deficiencies because they can be linked with many different etiologies. Prolonged deficiencies can exacerbate to more serious conditions, such as decreased bone mineral density, anemia, diabetes, cardiovascular and kidney disease[2,7]. Micronutrient deficiencies can develop because of many different factors, including but not limited to under consumption of the nutrient, low energy availability, elevated demands, and difficulties with absorption or metabolism of the nutrient[1,6-8,17]. The compounding effects of these situations overtime can cause health and performance implications to the athlete that can reduce their time of play or potentially cease all activity completely until the problem is resolved.

Athletes and Micronutrient Deficiencies

Appropriate and adequate intake allows the athletes to continue performing at a high level while adequately recovering, reducing the risks of injuries, and progressing with their training [6-8,15,18]. When an athlete is consistently in an energy deficit, there is a heightened risk of detrimental health and performance consequences[3,9,17,21].

Current research indicates the selected micronutrients assessed in this study have the largest potential impact on student-athletes and emphasis is placed on adequate consumption of these nutrients within the diet[1,3,6-9,17]. Inadequate consumption of vitamin D and calcium has been associated with lowered bone mineral density and an increased risk of bone related injuries, such as stress fractures, a common injury among athletes [1,8,17,22,23].

Insufficient iron levels and anemia can negatively impact an athlete's performance because of inadequate oxygen being transported to the muscles during times of exercise[1,7,8]. Athletes may experience increased levels of fatigue and the inability to adapt to training, negatively impacting performance. Vitamin C, an enhancer for iron absorption [2,7,24]. Not only does it increase the absorption ability of dietary iron, but it also acts as an anti-inflammatory agent, improving an athlete's ability to recover by reducing prolonged inflammation within the body[1,24,25]. Low levels of magnesium can also inhibit recovery in athletes and should be recognized among the others as an important micronutrient in the dietary intakes of student-athletes[7,26]. Research is continuing to accumulate regarding magnesium's role in the body's ability to recover following training, but current research indicates adequate levels of magnesium can reduce exercise-reduced inflammation and maintain the muscles integrity, allowing an athlete quicker recovery time following intense training loads[7].

Overview of Nutrients Important for Athletes:

The following vitamins and minerals were selected because of their significance in health and performance and the significant amount of research associated with athletes and the detrimental effects deficiencies can have on performance[1,3,6-9,17]. It is acknowledged that these are not the only nutrients that can negatively impact health and performance when under consumed, but these have significant research associated with the negative impacts at present. RDA values for each selected micronutrient is indicated in Table 1.

Table 1. Recommended dietary allowance for nutrients.

	Females 19-30 y	**Males 19-30 y**
Vitamin D	15 mcg	15 mcg
Calcium	1,000 mg	1,000 mg
Iron	18 mg	8 mg
Vitamin C	90 mg	75 mg
Magnesium	400 mg	310 mg
Abbreviations: mcg = microgram, mg=milligram		

Vitamin D

Vitamin D benefits the body through its role in supporting and regulating bone health and assisting with the absorption of calcium into the cells[17,22,23]. In addition to assisting with the regulation of calcium levels, vitamin D is also associated with maintaining skeletal muscle health and supporting our immune function[17,23]. Sufficient vitamin D levels are critical for all individuals in reducing the risk of bone injuries, such as stress fractures[8,17,22,23]. Vitamin D can be obtained from the diet, although foods containing the nutrient are limited[8,17,23]. Aside from dietary consumption of vitamin D, another way of obtaining the nutrient from UVB rays from the sun being absorbed through the skin [1,22]. Current research suggests that sufficient levels of vitamin D can "be obtained through 600 IU/day of dietary vitamin D, even in the absence of sun exposure" but McClung et al. believes that is an underestimated value according to emerging research surrounding optimal vitamin D dietary intake[8]. Many studies have concluded that athletes are under consuming the necessary amounts of vitamin D, leading to suboptimal blood levels. Despite the vitality of having sufficient levels of vitamin D to promote bone health in athletes, it is not unusual for athletes to have insufficient of deficient levels of vitamin D because of the difficulties associated with obtaining the nutrient from the diet as well as from the sun. Vitamin D deficiency, 25(OH)D blood levels < 20ng/mL, is a concern for many athletes playing both indoor and outdoor sports[1,6]. One study reported that 33-42% of female athletes may have insufficient blood 25(OH) D levels[8]. Other studies have concluded vitamin D insufficiency ranges from 13.3%-80% and vitamin D deficiency rates of .05%-72.8% in various athletes[1,6]. Specific factors can contribute to an athlete's risk of developing vitamin D deficiency, including time of year, location, darker skin pigmentation, amount of time spent outside, and skin exposure from clothing worn[1,8]. With sun absorption being a primary contributor to vitamin D status, dark pigmented skin tones are reported to have a higher risk of developing vitamin D deficiencies because the melatonin levels in the skin interfere with the absorption rates of the UVB rays[1,6]. Athletes who identify with these factors should be cautious of the increased risk they present for low vitamin D status.

Calcium

Along with vitamin D, calcium plays a vital role in the development and maintenance of bone health[8]. Without sufficient levels of calcium, the bone integrity can disintegrate, leading to serious implications like stress fractures or decline in bone mineral density[1,8,27]. Reduced bone mineral density can develop into serious medical conditions like rickets in children and osteomalacia and osteopenia in adults[8]. The micronutrients impact on bone health is so essential that in 2010 the Institute of Medicine (IOM) took the initiative to update the dietary reference intake levels of dietary calcium and vitamin D with bone health as the main motivating factor in their decision. According the NHANES data, both males and females under consume the recommended amounts of dietary calcium [8]. Contrary to vitamin D, calcium can be found in more foods, most commonly in dairy products.

Iron

The primary role for iron includes supporting the production of proteins, known as hemoglobin and myoglobin, in the transportation and storage of oxygen to different regions within the body[8]. The easiest way to absorb iron is through the consumption of heme iron, which is abundant in animal products including red meat, poultry, and seafood. The other type of dietary iron is nonheme iron and is found in plant products and is not as bioavailable as heme iron. Other nutrients associated with non-heme iron foods, like phytates and phenolic compounds interfere with absorption[8]. Foods rich with ascorbic acid, found in citrus fruits and leafy green vegetables enhance iron absorption and are essential in obtaining satisfactory iron levels[8]. The RDA for iron varies for females and males. It is recommended for females 18 mg/day and males 8 mg/day, because of monthly blood losses associated with menstruation[8]. One article determined that 67% of athletes do not meet the RDA values of iron[6]. Iron deficiency is common among athletes, reported 4-50% of male athletes and 20-50% of female athletes, but some studies suggesting the prevalence is above 50% [3,15].

There are multiple contributing factors to affect iron levels within the body. Low overall intake, low animal protein consumption, under consumption of iron-rich foods, and external factors contribute to low iron levels in the body[6-8]. Athletes have an elevated risk of developing deficiency or anemia because of decreased iron absorption following intense exercise. Acute inflammation as a response to physical activity increases the levels of hepcidin circulating in the blood. Hepcidin, a hormone that regulates iron levels in the blood, becomes elevated and reduces iron's absorption rate, contributing to decreased iron stores[8,9]. Iron losses associated with hemolysis from repetitive ground strikes in endurance athletes and/or gastrointestinal bleeding following intense exercise is another hinderance for athletes to combat when maintain adequate iron stores[8,17]. Female athletes have an additional barrier to increasing iron stores because of monthly blood losses from menstruation, which provides major iron losses via excretion in the blood, especially for those athletes with heavy menstrual cycles[8,9,17]. Any athlete consuming a restrictive diet, especially limiting sources of heme iron, increases the risk of iron deficiency [9,17]. The most prevalent symptom associated with insufficient blood levels of iron is decline in athletic performance due to the lack of oxygen carrying capacity from the red blood cells [8,17]. This can be detrimental to athletic performance, reducing endurance capacity and inducing muscle fatigue[7,8]. Iron acts as a cofactor in the brain as well as the skeletal muscles, so decline in concentration, behavior, and cognitive function is also associated with iron deficiency[8].

Vitamin C

In the body vitamin C contributes to many functions, including collagen tissue synthesis, absorption of iron from the blood stream, synthesis of hormones, and acts as an antioxidant to reduce reactive oxygen species (ROS) that could potentially cause harm to tissue[24,25]. For athletes it is important to consume recommended amounts of vitamin C daily to maintain the redox balance and reduce inflammation following physical activity. The RDA for vitamin C is 75 mg/day for women and 90 mg/day for men[20]. Regular consumption of fruits and vegetables accounts for a majority of a person's daily intake of vitamin C[25]. According to Jordan et al. the nutrient is found in a variety of fruits and vegetables, and it is uncommon for athletes to consume less than the RDA [6]. Controversially, Bird et al. found deficiency of vitamin C in 8.7% of adult males aged 19-50 years and contributed this finding to the lack of fruits and vegetables selected for consumption in their diet[2]. The article also associated the varying motivational factors for incorporating fruit and vegetables into the diet as a "gender-based difference" [2]. Under consumption of vitamin C can lead to poor recovery, inhibiting future performance in athletes.

Magnesium

Many functions that occur within the human body are reliant on magnesium to regulate processes and function as a cofactor for the numerous enzymes involved. A function of significance includes acting as an electrolyte or an electrical charge associated with skeletal and myocardial tissue contractions. Electrolytes act to regulate muscle function during exercise, prevent muscle cramps, and can regulate blood pressure[26]. Magnesium also functions to support energy metabolism, and emerging evidence shows that it may contribute to the maintenance of muscle mass and systemic inflammation, all important factors for athletes to be aware of[7,26]. The RDA for magnesium is 400 mg for males and 310 mg for females, with approximately 10% of our magnesium requirement coming from our drinking water [20,26]. Despite the contribution stemming from water, many people are not obtaining the recommended daily intake values of magnesium likely leading to insufficient or deficient levels[6,26]. When deficiencies are present a widespread number of diseases can develop, including hypertension, coronary artery disease, stroke, heart failure, chronic obstructive pulmonary disease, among others[26]. Limited research is available assessing the intake of athletes, but deficiencies could negatively impact their ability to recover and adaptation to training.

Dietary Analysis

Accurately recording participants dietary intake is a difficult task because of the many variables associated with the process and should be addressed when collecting data [28]. Dietary recalls rely on the participant to recollect and accurately depict their previous meals, leading to unintended reporting errors. These inconsistencies must be considered when deciding the way to collect recalls[28-30]. Of the multiple methods for recording dietary intake, two main categories exist: real-time recording or methods of recall [28]. Real-time recording allows the participant to keep a food diary and record each food or beverage consumed in the moment it is ingested [28]. The alternative to real-time recording is methods of recall, which relies on the participants memory to accurately depict their dietary intake [28]. Food frequency questionnaires are one method for collecting dietary intake data. This method requires the participant to determine how frequently they consume each of the listed foods groups [28]. The food groups can be broad categories or list specific food items, depending on the assessment. Difficulties arise when the food frequency questionnaire is relatively short in length and underestimates the variety of a participant's diet, unable to accurately depict a usual intake. However, if a long food frequency questionnaire is provided to participants, they could experience fatigue and rush through the questionnaire, again, reducing the accuracy of the diet reflected from the questionnaire [28].

An alternative form is the 24-hour dietary recall, which assesses a participant's daily intake from a 24-hour time frame, typically the previous day. The intention for a 24-hour recall is to gather information regarding the participant's typical intake daily [28,29]. It is likely that one day does not accurately depict an individual's usually daily intake, so it is recommended multiple recalls be collected to obtain a better representation of the usual intake. This method of dietary analysis is the standard for data collection, and current research suggests using at least three recalls for each participant, with some researchers suggesting using upwards of 8-32 recalls[28,29]. One drawback of using this many recalls is reliance on the participant and ensuring they maintain interest in providing detailed descriptions of their daily intake. Another limitation associated with 24-hour recalls is the difficulty for untrained individuals to accurately depict their true dietary intake when estimating the amounts of each food category they consume [28,30]. The participants may or may not understand what a serving size is for each item, reducing the accuracy and reliability when comparing the recalls against each other or to recommended standard. Both food frequency questionnaires and 24-hour recalls pose the risk of recall bias[28]. This occurs when participants intentionally refrain from reporting their complete diet history or adjust aspects of their recall, causing it to become inaccurate. It can be difficult to account for these types of errors, but it is encouraged by all researchers to limit these occurrences as possible. Using a consistent, uniform approach for obtaining each participant's recall can limit the amount of variability between each assessment, strengthening the reliability of the collected data.

Methods

Participants

All participants were members of the University track and field team. Track and field athletes (n=37) were recruited from a NCAA DI Power 4 university within the Southeastern region, no compensation was provided, and all participants were volunteers who wanted to learn more about their own micronutrient consumption habits. Of the 37 student-athletes (age: 20±1.21 years), 15 were females and 22 were males. Participants belonged to one of four track and field event groups: jumps, sprints, pole vault, or multi/combined. For this study, multi or combined event group athletes consisted of male athletes who compete in the decathlon outdoors or heptathlon indoors, and female athletes who compete in the heptathlon outdoors or pentathlon indoors. Distance and throwing event groups were not included in this study. Any athlete who was unable to complete the study or decided to discontinue was removed from the sample population. Characteristics of the participants can be seen in Table 2. Approval was obtained from the institution's Institutional Review Board (IRB) and procedures were conducted in accordance with the principles associated.

Procedures

A dietary analysis of each participant was conducted, and 24-hour dietary recalls were used to obtain accurate depictions of the athlete's intakes. This method was selected due to the ease of obtaining an accurate depiction of a daily routine without the incumbrance and potential inaccuracy of multiple-day food and supplement logs. Multiple dietary recalls were conducted for each student-athlete participating in the study, including weekdays and weekends, to gain an accurate representation of their daily intake during the off-season or non-competition portion of the collegiate track & field season from August through December[28]. The "hand method" was used to help the student-athletes accurately describe the portion sizes they consume at each meal. This method provides a convenient tool to estimate portion sizes without requiring equipment such as food models or measuring cups[30]. Each subject had a face-to-face in-person interview with the registered dietitian who completed each 24-hour diet recall, including all foods, beverages, and supplements consumed, the time consumed, portion sizes, where consumed, preparation methods, and whether ice was included in the beverage. In addition, each subject answered questions regarding the type of oil, margarine, milk, and bread frequently consumed. This consistent, uniform approach for obtaining each participant's recall was utilized to limit the amount of variability between each assessment. The recalls were then input and analyzed by the registered dietitian using Nutritional Data System for Research (NDSR) software version 50, 2019. The student-athletes micronutrient consumption and total calorie intake were collected for comparison to the RDA for each nutrient.

Table 2. Demographics of participating student athletes.

Participant Characteristics		**N (%)**
Gender	Female	15 (41%)
	Male	22 (59%)
Age	18	2 (5%)
	19	14 (38%)
	20	9 (24%)
	21	7 (19%)
	22	4 (11%)
	23	1 (3%)
Event	Jumps	10 (27%)
	Sprints	12 (32%)
	Multi	8 (22%)
	Pole Vault	7 (19%)
Race	African American	20 (54%)
	Caucasian	16 (43%)
	Other	1 (3%)
Year of Eligibility	Freshman	5 (14%
	Sophomore	13 (35%)
	Junior	9 (24%)
	Senior	10 (27%)
Residence	Off-Campus	30 (81%)
	On-Campus	7 (19%)

Statistical Analysis

Statistical analyses were conducted using SPSS statistical software version 29 and Microsoft Excel. Descriptive statistics were conducted to determine participant characteristics, micronutrient intake, and total calories. Weekend and weekday intake were not separated during the statistical analysis. Chi-square tests were conducted to determine any significant correlations between micronutrient intake and participants demographic variables. Statistical significance was set at $p<0.05$. A post-hoc G*Power Index was run to assess statistical power.

Results

All subjects exhibited underconsumption of at least one specific micronutrient, with many subjects failing to meet the RDA for multiple micronutrients. Only one subject consumed the recommended amount of dietary vitamin D. Despite the lack of prevalence in foods, vitamin D has an abundance of availability coming from the sun's rays that could provide an athlete with substantial amounts to prevent insufficient or deficient levels. Removing vitamin D intakes from the analysis, 92% (n=34) of student-athletes were still under consuming at least one of the selected micronutrients when compared to the RDA. Table 3 categorizes the participants into separate groups, representing the number of selected micronutrients each athlete under-consumed compared to the recommendations.

Table 3. Prevalence of under consuming relative to the recommended dietary allowance for multiple micronutrients (excluding Vitamin D).

	Number of Micronutrients with Insufficient Intake				
	0	**1**	**2**	**3**	**4**
Females	0 (0%)	1 (7%)	3 (20%)	3 (20%)	8 (53%)
Males	3 (14%)	3 (14%)	5 (23%)	11 (50%)	0 (0%)

Results from the descriptive analysis portrayed some significant correlations among participant characteristics and under consumption of each micronutrient. Table 4 depicts the number of participants under-consuming each micronutrient separated by gender. Four out of the five micronutrients did not have significant results comparing adequate intakes to each gender. Iron, however, did show a significant relationship with 100% of the male participants consuming the recommended dietary iron amounts, while only one female participant met the recommendation, χ^2 (1, N = 37) = 33.03, $p < 0.001$.

Table 4. Number of subjects with insufficient intake of specific analyzed micronutrients.

	Females	**Males**	**Total**
Calcium	13 (87%)	14 (64%)	27 (73%)
Iron	14 (93%)	0 (0%)	14 (37%)
Magnesium	12 (80%)	18 (82%)	30 (81%)
Vitamin C	9 (60%)	14 (64%)	23 (62%)
Vitamin D	15 (100%)	21 (95%)	36 (97%)

The most common micronutrient to be under consumed by all participants was magnesium at 81% (n=30), followed closely by calcium at 73% (n=27). There was a significant difference in the magnesium consumption amongst African American and Caucasian participants, χ^2 (2, N = 37) = 6.360, $p = 0.042$, with more Caucasian participants consuming the recommended amounts of magnesium compared to African American participants. One out of twenty African American participants met the recommendations (5%) while 38% of Caucasian participants consumed adequate amounts of magnesium. Additionally, there was a significant association between the consumption of calcium and living on-campus, χ^2 (1, N = 37) = 3.970, $p = 0.046$ (Table 5).

Table 5. Statistical analysis of micronutrients.

	Vitamin D	**Calcium**	**Iron**	**Vitamin C**	**Magnesium**
	Chi-square	Chi-square	Chi-square	Chi-square	Chi-square
Gender	1.507	2.399	33.032***	0.05	0.019
Age	4.405	12.372*	5.569	2.684	15.839**
Event	2.141	3.433	0.943	2.537	4.203
Race	0.874	4.106	1.712	4.316	6.360*
Year of Eligibility	2.775	8.792*	2.174	2.435	2.137
Residence	0.240	3.970*	2.036	1.368	0.524

Note: *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

Nearly every athlete living on-campus met the recommended intake for calcium, while upperclassmen, who mainly live off-campus, fell into the inadequate range. Aside from the previously mentioned, no other characteristics showed significant differences in micronutrient intakes, and consumption of the selected micronutrients was evenly dispersed between each event group. According to the post-hoc G*Power analysis, it was indicated that the statistical power was relatively low (44%) compared to the normative standard (80%), likely due to the relatively small sample size.

Discussion

The purpose of this study was to determine the prevalence of student-athletes consumption of micronutrients compared to the RDA values. Athletes failing to meet dietary intake recommendations for micronutrients does not necessarily mean they will certainly develop biological deficiencies, but it is a noteworthy associated risk[7]. The data collected shows 100% of participants were under-consuming at least one of the selected micronutrients. Some nutrients were consumed at a higher rate, with some participants meeting the RDA, while others were significantly under consumed.

In accordance with previous research, the under-consumption of micronutrients could be attributed to under-consumption of total calories[6,8,10,17]. Individual estimated energy recommendations for each student-athlete were unable to be obtained during this study but compared to the 2,000-calorie recommendation for the general population, thirty-two percent of these student athletes are failing to meet their estimated energy needs. This is likely an underestimate for calorie needs if you consider the assumption that majority of collegiate, Division I student-athletes have higher energy demands than the generalized 2,000-calorie predictor, indicating a higher percentage of participants consuming low energy intakes. Individuals under consuming their recommended caloric intake limits the availability of micronutrients within their daily intake, putting each athlete at a disadvantage for obtaining the essential micronutrients from their diet and increasing the risk of adverse effects associated with micronutrient deficiencies. Students living on campus tend to have an advantage because of the accessibility to dining halls and restaurants universities strive to acquire. Despite the abundance and convenience of food on campus, 86% (6 out of 7) of students living on campus still were under consuming at least one micronutrient, primarily magnesium, where all but one student met the RDA. The other participant characteristics were not notable when comparing intakes.

Calcium

The results from the collected data indicated that student-athletes living on-campus consumed more dietary calcium on average compared to those students living off-campus. These findings were opposite of initial assumptions that older students, the upper classmen electing to move off-campus, would consume higher amounts of calcium compared to the freshman, who were required to live on-campus. More exposure to performance nutrition and experience living on their own leads to the assumption that students living off-campus, who can make more of their own decisions and purchase their own groceries, would be consuming more calcium, but the results indicated otherwise. One reason we could conclude for this finding is the convenience of calcium-rich foods on campus, via dining halls, restaurants, or convenience stores that was included in the students dining plan.

Emphasizing calcium-rich foods in the diet should be a standard practice for those working with student-athletes to instill the importance of the nutrient on their health and to help them recognize how calcium can be under consumed if not intentionally incorporated into a daily routine. Even though calcium is more prevalent in foods compared to vitamin D, many of those prospective foods are dairy products[27]. Student-athletes who avoid dairy, whether due to medical reasons or personal preference, should be aware of the potential risk of calcium deficiency in their diet. To support proper bone health and minimize the risk of related injuries, they should seek alternative sources of calcium to ensure sufficient intake[24].

Iron

There was a significant difference of dietary iron consumption from male to female participants. When looking at the average iron intakes, all participants consumed similar amounts with a mean intake of 15.78 ± 0.76 mg/d. Females have a higher RDA for iron compared to men, 18 mg/d versus 8 mg/d. This increase in the RDA led to an overwhelming majority of females under-consuming dietary iron and put these individuals at a higher risk of developing insufficient iron levels or anemia[8,32]. An article by Weight et al. concluded similar results from their study analyzing dietary iron intakes in male and female athletes. From their cohorts, the male's average dietary iron intake met the RDA, averaging 14.8 mg/day, but the female's average failed to meet their respective RDA, averaging below 18 mg/day[33]. Another study assessing the dietary intakes among female marathon runners concluded that prior to their studies intervention, none of the female athletes met the prospective RDA[34]. The article findings, along with the present study indicates an increased emphasis of nutrition education for female athletes regarding the difficulty of reaching the recommended intake for iron. Many things inhibit the absorption of iron into the body, including increased hepcidin levels following exercise, other mineral rich-foods, and compounds found in plant foods like phytates and phenolic compounds[8]. The bioavailability of iron, or lack thereof, places another obstacle for athletes and further emphasizes the importance of proper dietary intake of iron[8].

Magnesium

Magnesium was the most commonly under-consumed nutrient among subjects. There were no significant differences among the participant characteristic groups. One finding of interest was the group of seven participants that met the RDA for magnesium had higher total caloric intakes than the other participants, supporting the notion that consuming a diet that meets energy needs can provide student-athletes with the recommended micronutrient needs[6,7,17]. Other studies have concluded magnesium to be a difficult nutrient to obtain the RDA in most athletes' diet[6,7]. Nutrition education surrounding magnesium rich foods is essential for student-athletes to ensure they are maintaining well-rounded, substantial diets to provide them the micronutrients they need to maintain a healthy lifestyle and perform at their highest potential.

Vitamin C

The result from the analysis shows that a majority of subjects failed to meet the recommendation for dietary intake of vitamin C. However, current literature continues to suggest that inadequate consumption of vitamin C is not common among athletes or the general population[6,35]. However, an article from 2017 concluded 49% of participants did not meet the recommended intake value when assessing dietary consumption compared to the EAR[2]. Socioeconomic status is a potential contributor to dietary vitamin C intake levels and could be a factor in the increased prevalence of under-consuming the RDA in this study's population[25]. A lack of nutrition knowledge encompassing the benefits of vitamin C, not only on health but in different roles of performance, could be a limitation for these student-athletes failing to consume adequate amounts of dietary vitamin C.

Vitamin D

This was not shocking considering the lack of vitamin D-rich foods and the availability of vitamin D coming from UVB rays. Despite the limited amounts of vitamin D-rich foods, dietary vitamin D still has a significant place in the diet of student-athletes, as well as the general population, because of the difficulties associated with obtaining an ample amount of vitamin D from the sun to promote adequate blood levels, a vital component for many functions within the body. The study's population displayed comparable results of dietary under-consumption compared to similar studies assessing vitamin D dietary intake, approximately 2.7% and 5% of college athletes obtaining the RDA from dietary sources alone [23,27]. There is even debate that the current RDA for vitamin D is low compared to actual needs, especially when some populations have difficulties with absorbing adequate amounts of vitamin D from the sun's rays. For example, individuals with darker pigmentation, indoor sport athletes, those living in northern regions of the country and the amount of clothing or SPF worn outside[8,23]. The impact vitamin D has on many functions within the body, primarily its role regulating bone health, warrants special attention when analyzing an individual's intake and focusing on obtaining adequate levels of vitamin D[7,22,23]. When dietary intake is limited and factors that inhibit absorption from UVB rays, supplementation should be considered to bridge the gap for these student-athletes at risk of deficiency.

Strengths and Limitations

Using multiple 24-hour dietary recalls improved the representation of each participant's usual dietary intake and allowed for more accurate estimations of their micronutrient consumption. Alternative methods of dietary analysis could risk increased room for error and uncertainty when analyzing the caloric and micronutrient intakes of the participants. Each recall was conducted or analyzed by a Registered Dietitian. The software used for dietary analysis had a data base of many different foods, including name branded, packaging, and common fast food menu items, which eliminated estimations and uncertainties when logging these items and provided a more accurate depiction.

While lengths were taken to minimize any limitations associated with this study, there are some that could not be avoided. Any form of dietary analysis contains the potential for slight errors or inaccuracy due to it relying on the memory of each student-athlete and their ability to accurately describe their intakes. These student-athletes do not have a background in nutrition and struggle to accurately depict a portion size for a meal. Estimations were made to best determine accurate intakes, including incorporating the "hand method" for a more accurate depiction, but room for error must be considered when analyzing their caloric and nutrient results. Researchers were unable to assess blood biomarkers during this study, however future research may benefit from utilizing blood biomarkers confirm the idea that chronic under consumption of micronutrients can lead to deficiency. Micronutrient deficiencies may increase the potential of experiencing negative performance outcomes as well as detriments to the student-athletes' health. This would have been especially beneficial for vitamin D to determine if the under consumption of vitamin D from food alone accurately represents detrimental health effects even though the most abundant source of obtaining vitamin D is from UVB rays from the sun. Blood results of the nutrients could also confirm the accuracy from the diet recalls in representing the athlete's actual intakes.

The researchers also recognize that the post-hoc power analysis using G*Power indicates low statistical power primarily due to the relatively small sample size. However, this constraint appears to be common across studies involving specific team sports at a single university where recruitment possibilities and convenience sample sizes are inherently limited. Future research could explore the opportunity to do a multi-university study to increase the population sample size. While the sample size was low, causing G*Power to decrease, the significant findings observed suggest that the detected effect is clinically meaningful and has implications on future practice.

Conclusions

The findings of this study highlight the need for improved dietary education among student-athletes and emphasize the importance of assessing micronutrient intake within this population. Micronutrient assessment is beneficial both as a marker of general health and well-being as well as a factor influencing athletic performance.

Adequate micronutrient intake has broad implications on general health and well-being, reinforcing the value of comprehensive dietary assessments. Prioritizing student-athlete health through regular screening and early identification of potential deficiencies can support long-term well-being. Special attention should be given to athletes with limited access to dining halls, training tables, or other nutritional resources, as these individuals may be at greater risk for deficiencies. Food insecurity can affect students across all campuses, including scholarship athletes. Recognizing these barriers is essential for developing targeted and effective nutrition education initiatives.

Micronutrients play a key role in athletic performance by supporting energy metabolism, reducing fatigue, increasing recovery, and minimizing injury risk. Athletic programs should place an emphasis on monitoring and improving intake of micronutrients to increase overall athletic performance. Sport dietitians should ensure that student athletes receive well rounded nutritional support by assessing caloric, macronutrient, and micronutrient intake to help optimize outcomes and elevate the standard of care in collegiate athletics.

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