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Iron Deficiency in Collegiate Athletes: Effects of a Pragmatic Program for Assessment and Treatment

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Abstract-BACKGROUND: Iron deficiency has been shown to negatively affect sports performance. Iron deficiency is more common in female athletes than male athletes and among female athletes, those who are endurance trained are at a higher risk for iron deficiency. Many studies show iron supplementation has been shown to increase iron status in athletes. However, majority of these studies are research studies rather than pragmatic studies looking at the effectiveness of the program.

OBJECTIVE: We hypothesized that oral iron supplementation is effective in improving iron status, as determined from serum ferritin levels, in female student-athletes in the real-world setting.

METHODS: The study is a retrospective analysis of existing data that were collected as part of an iron monitoring and supplementation program that was implemented by the Department of Sports Sciences & Physical Education at Punjab University (division I). Sixty-four female athletes (age 18.3 ± 0.1 years, BMI 22.5 ± 0.4 kg/m2) were screened for the 2017-2018 academic school year. Fifty- one of them were incoming freshmen athletes from any sport (age 17.8 ± 0.1 years, 23.1 ± 0.5 kg/m2) and thirteen of them were upperclassmen on the cross-country team. Two females were cross-country runners and freshmen female athletes, meaning the cross-country team included 15 female runners (age 19.7 ± 0.3 years, 20.3 ± 0.5 kg/m2, dietary iron intake 8 ± 1 mg per day). Incoming freshmen were screened at baseline from May – August 2017 while the upperclassmen cross-country runners were screened at baseline from July – October 2017. Those who were iron deficient (serum ferritin < 20 ng/mL) were advised to begin oral iron supplementation and instructed to follow up, per physician recommendation. The monitoring and intervention program began May 2017 and ran through the 2018 spring semester. Data from the university athletics dietitian were compiled from the electronic medical record, were deidentified, and provided for analysis.

RESULTS: 18 (28%) of the sample had nonanemic iron deficiency, NAID. 16 (31%) of freshmen athletes had NAID which was a higher prevalence compared to the 2 (13%) from the cross-country team. Of those with NAID, 15 received prescribed iron supplementation and 2 received over-the-counter supplementation. 8 of the 18 (44%) underwent follow-up and 6 of the 8 (75%) had resolved NAID by the end of the program. This was a significant increase (p=0.03). CONCLUSION: Iron deficiency is improved with iron supplementation, despite the variability in pill compliance and bioavailability of iron. In a pragmatic setting, more aggressive intervention is needed for increased compliance and better follow-up.

KEY WORDS: sports nutrition, iron, deficiency, iron supplementation, fatigue, performance, ferrous sulfate, athletes, cross country, freshmen, female athletes, dietary iron, collegiate athletes

Introduction

Erythrocytes, or red blood cells, contain hemoglobin which gives them their red color. Hemoglobin contains iron which cooperatively binds oxygen. This gives red blood cells the ability to carry oxygen to muscles (Mahan et al., 2012). Because oxygen is necessary for energy production and availability, iron is necessary. Sufficient iron is especially necessary for sports performance because athletes respire at an increased rate and use more energy than sedentary individuals. Athletes, particularly female athletes, are at increased risk of compromised iron status due to iron losses through menstruation and exercise-induced metabolism (Alaunyte et al., 2015).A deficit of iron in the body can result in decreased immune function, temperature maintenance, energy metabolism, and sports performance (Rowland, 2012). Due to these adverse effects, low iron availability can impair an athlete's ability to perform at a high level. Therefore, research has been conducted surrounding iron and sports nutrition. Despite the detrimental effects of low levels of iron on athletic performance, Rowland has found that iron deficiency is common in athletes. While iron deficiency anemia (IDA) is uncommon in most athletes, nonanemic iron deficiency (NAID) is common among female athletes, particularly those who are endurance trained. It is expected that in trained endurance females, 25-33% have nonanemic iron deficiency (Rowland, 2012). Prospective studies have shown that iron supplementation increases serum iron values (Fogelholm, 1992). However, this is within an ideal setting where iron supplementation is controlled, and subjects are well-supervised. Oral iron supplementation can have side effects such as constipation, nausea, gastrointestinal distress such as cramps, etc., which may reduce "pill compliance" by patients who are prescribed supplements. Therefore, the study has two aims. The first aim is to identify the prevalence of iron deficiency among varsity collegiate female athletes in a division I university. The second aim is to supplement those with deficiency and then perform follow up assessments to determine if the supplementation was effective for normalizing iron status. This aim is designed to evaluate the pragmatic effectiveness of the iron supplementation program for improving iron status.We hypothesize that oral iron supplementation is effective in improving iron status, as determined from serum ferritin levels, in female student-athletes in the real-world setting despite variability in pill compliance and bioavailability of iron.

Methods

Study Design

The study is a retrospective analysis of existing data that were collected as part of an iron monitoring and supplementation program that was implemented by the Department of Sports Sciences & Physical Education Punjab University. The program was proposed by the Senior Associate Director of Athletics and was implemented by the athletic program's sports medicine physicians and the sports dietitian. The monitoring and intervention program began in May 2017 when the first-year student-athletes arrived on campus for their orientation to the university. It ran through the 2018 Spring semester. The sports dietitian compiled the serum ferritin values from the electronic medical record and worked with the team of physicians to follow up with athletes on an individual basis. Additionally, the registered dietitian studied compliance by conducting a food-frequency questionnaire on heme and non-heme sources of iron eaten over the course of a month for the cross-country team. She also provided education to the student-athletes, so they could learn sources of heme and non-heme iron, how often to eat them, and how to take the supplement.

Subjects

The program targeted freshmen female student-athletes (all sports) and members of the female cross-country team (freshmen through seniors). In total, the athletes who were targeted by this program included 51 female freshman athletes and 15 female cross-country team members (2 freshman female cross-country runners), for a total of 64 athletes who were targeted for inclusion in this program.

Iron Deficiency Monitoring

The screening aspect of the program consisted of assessments of serum ferritin concentration in all the targeted athletes (described above). Baseline ferritin levels were obtained from May – August 2017, despite exercise status for freshmen female student-athletes. For upperclassmen female student-athletes, the baseline ferritin values were obtained from July – October 2017. For follow up samples, venous blood samples were acquired from the athletes at least 12 hours after their most recent exercise-free bout and after confirming that they were free of illness. The samples were analyzed for serum iron concentration by a CLIA-certified clinical laboratory. Results from the serum ferritin analyses were retrieved from the athletes' electronic medical record. For females, serum ferritin levels < 20 ng/mL were considered "low" and reflective of inadequate iron status. High serum ferritin levels were >150 ng/mL and reflective of elevated iron stores. Overload was >200 ng/mL. Baseline values were taken as part of the athletes' physical medical examination; there was no control

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for variables such as when the athlete had last exercised or if she was illness free. However, most athletes had not exercised within 12 hours. Follow ups were generally the same but were only done in the absence of recent exercise and illness. Therefore, it is conceivable that baseline values were affected by recent exercise or illness while follow up values were not. The timing of follow-up assessments was generally planned to occur after 2-3 months of supplementation. However, the timing was largely variable due to athlete scheduling conflicts, impending competitions/games, and the clinical judgement of the physicians, with intention to treat.

Iron Supplementation

If serum ferritin concentrations were low, the athletes were prescribed oral iron supplements. The dose, frequency, and form of iron supplement were retrieved from the electronic medical record and were determined by the prescribing physician. Because there is more than one sports medicine physician, the methodology behind oral iron prescription may have differed. Some physicians prescribed oral iron, others would ask the student-athlete what pharmacy to send the iron to during the interaction at the clinic, others would recommend oral iron in the clinic then contact the student-athlete via electronic medical record asking which pharmacy was preferred, and still others would contact the student-athlete via electronic medical record and ask if oral iron prescription or over-the-counter iron was preferred based on the patient interaction. Interim measures of serum ferritin were performed for some athletes, depending on the severity of deficiency. In general, if the interim measures of ferritin were elevated to >70 ng/mL, the iron supplementation doses were reduced.

Data Acquisition

Data from the program were tracked and compiled by the athletic department's registered dietitian for the purpose of self-monitoring the effectiveness of their own program. For the purpose of the study, the athletic department shared a copy of their data from the program with the researchers for this study, after removing all personal identifier information. The information was shared in the form of an electronic spreadsheet with all personal identifiers removed.

Statistical Analyses

Descriptive statistics (means, SDs, SEs) were used to describe participants' characteristics. Outcomes were evaluated by using both a "per protocol" approach, which only included data from subjects who were not lost to follow-up. Additionally, outcomes were evaluated with an "intention-to-treat" analysis, which included data from all subjects who were enrolled in the iron supplementation program; missing follow-up values for the intention-to-treat analysis were estimated by using the last observation carried forward (LCOF) method.Comparisons of baseline and follow-up ferritin levels and any other quantitative measures were compared by using two-tailed, paired t tests. Categorical data was summarized as frequencies. A p-value of <0.05 was considered significant. Though we observed some statistically significant changes in outcomes during the program, the magnitude of change was also evaluated to determine if it had clinical significance. Statistical analyses were performed with Microsoft Excel software.

Results

Participants

Sixty-four female athletes underwent baseline iron status assessment as part of this program. As depicted in Table 3, these women had an average age of 18 years old, height of 65.5 inches (166.6 cm), weight of 139.3 lbs (63.3 kg), with BMI in the normal range. As was intended, all the athletes targeted and enrolled in this program were female freshmen athletes (any sport) and/or female cross-country runners (all classes/years). There were no female freshmen or female cross-country runners who did not participate in this program.

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Tables

Table 1: Differing Definitions for Nonanemic Iron Deficiency and Differing Tests Used

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Cook et al, 1986		
2 of 3: Serum Ferritin <12 ng/mL, Transferrin Saturation <16%, Serum Iron* <50 ug/dL, Free Erythrocyte Protoporphyrin>70 ug/dL RBC		
	Premenopausal Females	10%
	Post-menopausal Females	4%
	Males	1%
Serum Ferritin <12 ng/mL		
	Premenopausal Females	21%
	Post-menopausal Females	6%
	Males	2%
Dubnov, Constantini, 2004		
Serum Ferritin <20 ng/mL		
	Female Athletes	35%
	Male Athletes	15%
Pate et al, 1993		
Serum Ferritin <20 ng/mL		
	Female Athletes	50%
	Sedentary Females	22%
Looker et al, 1997		
2 of 3: Serum Ferritin <12 ng/mL, Transferrin Saturation <15%, Free Erythrocyte Protoporphyrin>1.24 umol/L RBC		
	Males	<1-4%
	Females	5-11%
Coates et al, 2017		
Serum Ferritin <25 ng/mL		
	Female Triathletes	60%
	Female Runners	56%
	Male Triathletes	38%
	Male Runners	31%

Table 1. Continued

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Serum Ferritin <15 ng/mL	
Female Triathletes	60%
Female Runners	11%
Male Triathletes	25%
Male Runners	0%
Landahl et al, 2005	
Certain Iron Deficiency: Serum Ferritin <16 ng/mL, Probable Iron Deficiency: Serum Ferritin 16-20 ng/mL, Hemoglobin >12 g/dL	
Female Soccer Players	57%
Clement, Asmundson, 1982	
Serum Ferritin < 25 ng/mL	
Female Athletes	82%
Constantini et al, 2000	
Serum Ferritin <20 ng/mL	
All Female Athletes	30%
Male Athletes of Other Sports	19%
Male Gymnasts	36%
Ostojic, Ahmetovic, 2009	
Serum ferritin <12 ng/mL, Transferrin Saturation <16%, Hemoglobin >14 g/dL	
Male Soccer Players	9-12%
Alaunyte et al, 2015	
Serum ferritin <12 ng/mL	
Active/Athlete Males and Females	18-57%
Fogelholm, 1995	
Serum Ferritin 12-20 ng/mL	
Female Athletes	37%
Female Nonathletes	23%

Table 1. Continued

Wijn et al, 1971	
Serum Iron <70 ug%, Transferrin Saturation <15 %	
Female Athletes	15%

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Male Athletes	5%

* when transferrin saturation was not available.
-Some units were converted for ease in data comparison

Table 2: Differing Definitions for Iron Deficiency Anemia and Differing Tests Used

Cook et al, 1986	
2 of 3: Serum Ferritin <12 ng/mL, Transferrin Saturation <16%, Serum Iron* <50 ug/dL, Free Erythrocyte Protoporphyrin>70 ug/dL RBC, and Hemoglobin <12 g/dL in Females and <13 g/dL in Males	
Premenopausal Females	2%
Post-menopausal Females	1%
Males	<1%
Hemoglobin <12 g/dL in Females and <13 g/dL in Males	
Premenopausal Females	8%
Post-menopausal Females	5%
Males	2%
Killip et al, 2007	
Serum ferritin <15 ng/mL, Transferrin Saturation <5%, Mean Corpuscular Volume <70 fL, Hemoglobin < 12 g/dL in Females and <13 g/dL in Males	
Females	3%
Males	2%
Coates et al, 2017	
Hemoglobin <12 g/dL in Females and <14 g/dL in Males	
Female Triathletes	20%
Female Runners	0%
Male Triathletes	25%
Male Runners	6%
Serum Ferritin <25 ng/mL, Hemoglobin <13 g/dL	
Male Triathletes	25%
Male Runners	0%
Wijn et al, 1971	
Serum iron <70 ug%, Transferrin Saturation <15%, Hemoglobin <12 g/dL in Females and <14 g/dL in Males	
Female Athletes	3%
Male Athletes	2%

Table 2. Continued

Dubnov, Constantini, 2004	

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Serum Ferritin <12 ng/mL, Transferrin Saturation <16%, Hemoglobin <12 g/dL in Females and <14 g/dL in Males	
Female Athletes	14%
Male Athletes	3%
Athletes	75
Pate et al, 1993	
Serum Ferritin <20 ng/mL, Hemoglobin <12 g/dL	
Female Athletes	3%
Sedentary Women	3%
Ostojic, Ahmetovic, 2009	
Serum Ferritin <12 ng/mL, Transferrin Saturation <16%, Hemoglobin <14 g/dL	
Male Soccer Players	6%
Landahl et al, 2005	
Hemoglobin <12 g/dL	
Female Soccer Players	25%
Looker et al, 1997	
2 of 3: Serum Ferritin <12 ng/mL, Transferrin Saturation <15%, Free Erythrocyte Protoporphyrin>1.24 umol/L RBC, and Hemoglobin <12 g/dL in Females and < 13 g/dL in Males	
Females	2%
Males	<1-2%

-Some units were converted for ease in data comparison

Table 3: Subject Characteristics

	All Athletes	XC	Freshmen Athletes
Age, years	18.3 ± 0.1	19.7 ± 0.3	17.8 ± 0.1
Height, cm	166.6 ± 0.7	165.8 ± 1.4	166.7 ± 0.8
Body mass, kg	63.3 ± 1.4	56.1 ± 1.9	65.1 ± 1.6
BMI, kg/m^2	22.5 ± 0.4	20.3 ± 0.5	23.1 ± 0.5

Table 4: Iron Supplementation and Frequency

	All Athletes	XC	Freshmen Athletes
Ferrous sulfate daily, 65 mg/d	6 (40%)	1 (7%)	5 (33%)
Ferrous sulfate BID, 130 mg/d	7 (47%)	0 (0%)	7 (47%)
Ferrous sulfate TID, 195 mg/d	1 (7%)	0 (0%)	1 (7%)

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Iron polysaccharide BID, 300 mg/d	1 (7%)	1 (7%)	0 (0%)

**Iron equivalents do not include prior prescriptions they may have taken, over-the-counter supplements, or dietary sources they may have ingested. BID, bis in die (twice daily); TID, ter in die (three times daily).

Table 5: Serum ferritin values at baseline and follow-up in athletes with baseline deficiency

	Baseline(ng/mL)	Follow-Up (ng/mL)	P-Value
Per protocol analysis	12 ± 2	30 ± 7	0.03
Intention-to-treat analysis	11 ± 1	19 ± 4	0.04

Table 6: Serum ferritin values at baseline and follow-up in athletes with normal serum ferritin levels at baseline.

	Baseline(ng/mL)	Follow-Up (ng/mL)	P-Value
Per protocol analysis	40 ± 4	40 ± 6	0.93
Intention-to-treat analysis	44 ± 3	45 ± 3	0.93

Table 7: Iron Supplementation-Compliance of Information Among Athletes Who Were Prescribed Supplements and Provided Follow Up Data (n=8)

Knew iron supplement was prescribed?	
Yes	8 (100%)
No	0 (0%)
Picked up supplement?	
Yes	6 (75%)
No	2 (25%)
Took supplement as frequently as prescribed?	
Always	2 (25%)
Most of the time	3 (38%)
Rarely	2 (25%)
Never	1 (13%)
Reason for not taking supplement?	
Constipation	2 (25%)
Stomach upset	1 (13%)
Constipation + stomach Upset	1 (13%)
None	4 (50%)
Other	0 (0%)
Co-ingestion with meal?	
Yes	2 (25%)
No	2 (25%)
Not specified	4 (50%)

Dietary Iron Intake

Based on quantified dietary iron intake, the females on the cross-country team averaged an intake of 8 ± 1 mg per day. This is 45% of the RDA for females in this age group.

Prevalence of Iron Deficiency and Excess

Among the sixty-four female student-athletes, eighteen (28%) had low serum ferritin at baseline, suggesting the presence of iron deficiency. When looking solely at the cross-country team 2 (13%) of the cross-country runners began the season with low serum ferritin (n=15). Among freshmen female athletes 16 (31%) had low serum ferritin at baseline. Forty-five (70%) of

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all female athletes had normal serum ferritin values. Of these, twelve (80%) of the cross-country runners had normal values and 35 (69%) of the freshmen athletes had normal values.

Only one (1.5%) of the female athletes had high serum ferritin values. She was on the cross-country team and thus represented 7% of the team.

Iron Supplementation

Fifteen female athletes received prescriptions for oral iron supplementation. Most (47%) female athletes with low serum ferritin values at baseline were prescribed ferrous sulfate oral supplements twice daily (Table 4). Daily ferrous sulfate was prescribed to 6 (40%) of the female athletes with low serum ferritin values at baseline, making it the second most frequently prescribed supplement. Only one (7%) of the athletes was prescribed ferrous sulfate three times per day and one (7%) was prescribed iron polysaccharide twice daily. All eighteen female athletes with low serum ferritin were advised to take oral supplements. Fifteen were prescribed oral iron supplementation and two participants were advised to take over-the-counter oral iron supplements after their parents expressed this preference. One female student-athlete refused supplementation (prescription and over-the- counter) because she had a negative experience with iron deficiency anemia in high school and did not want to get more blood tests in college.

Ferritin Response and Supplementation in Participants with Baseline Deficiency

There were 18 female athletes with low serum baseline ferritin concentrations; 8 of these individuals were treated with iron supplements and underwent follow-up testing according to protocol. Results from these individuals were included in a "per protocol" (PP) analysis. For an "intention-to-treat" analysis (ITT), individuals who did not provide follow-up data (n=10) were included by assuming that their follow-up ferritin values were unchanged from baseline (last observation carried forward). Fifteen female athletes were placed on prescription iron supplementation and two on over-the-counter iron supplements. Both female athletes who were placed on over-the-counter supplements were lost to follow-up. The 8 athletes who underwent follow up (PP), had a mean ferritin concentration of 30 ± 7 ng/mL at follow-up, which represented a 58% increase from baseline (p= 0.03). For the ITT analysis, which assumed unchanged serum ferritin values for those who were lost to follow-up, a significant 42% increase to 19 ± 4 ng/mL (p=0.04) in serum ferritin levels was also observed (Table 5).

Ferritin Response and Supplementation in Participants without Deficiency (not supplemented)

Among the 45 athletes who had normal baseline ferritin levels, none were supplemented but 12 provided followed up data. Table 6 shows that the mean serum ferritin values did not change for PP analysis (p= 0.93) from baseline (40 ± 4 ng/mL) to follow-up (40 ± 6 ng/mL). Likewise, in an ITT analysis that included all 45 athletes with normal baseline ferritin levels (those who did not get a follow up measure were assumed to be unchanged from baseline), serum ferritin values did not change (p=0.93) from baseline (44 ± 3 ng/mL) to follow-up (45 ± 3 ng/mL) (Table 6).Table 7 is a compilation of the results from a survey that was sent to the athletes who were low in serum ferritin at baseline and then followed up (n=8).

Discussion

The aims of this study were to two-fold. First, the purpose was to identify the prevalence of iron deficiency among varsity collegiate female students in a division I university. Second, the purpose was to supplement those with deficiency and then perform follow-up assessments to determine if the supplementation was effective for rectifying iron deficiencies.

Results show that a large portion of athletes from Punjab University's incoming female freshmen athletes and cross-country team from 2017-2018 had low serum ferritin levels (28%). Prevalence of iron deficiency was considerably higher in freshman athletes (31%, n=51) compared to the cross-country team (13%, n=15). This is an occult deficiency that would not have been known had it not been for this study. Supplementation was implemented in 15 of these individuals. Only 8 returned for follow-up assessments. Nonetheless, supplementation appeared to be effective for improving iron status, as evidenced by an increase in serum ferritin levels from baseline (12 ± 2 ng/mL) to follow up (30 ± 7 ng/mL), which was modest but statistically significant (p=0.03). This could imply clinical significance for those who took iron supplementation. Seventy-five percent of athletes with

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baseline deficiency who receive supplementation and follow-up assessments, exhibited increased serum levels above the cut-off value for deficiency of 20 ng/mL. The only athlete whose ferritin levels dropped stated that she never picked up her prescription, though she did buy over-the-counter supplements. She admitted to taking the supplement "most of the time," on an empty stomach, with vitamin c, and that she originally had constipation, but this subsided after a few weeks. Another individual did not emerge from a deficient state, though her serum ferritin increased minimally, she was on ferrous sulfate twice daily. She admitted to taking it rarely, indicating that she took the supplement whenever she remembered. One of her barriers to taking her supplement was due to the constipation she had. There was one other participant who indicated that she took her supplement "rarely." Despite this, her serum ferritin concentrations increased, possibly because she defined "rarely" as taking it more often than the other participant who indicated rare use of her iron supplement. Among the 64 female athletes who were involved in this iron monitoring program 28% had iron deficiency. This was not the entire population of female athletes that play division I sports at the university; therefore, this percentage could increase or decrease if the entire population was studied. However, 28% is consistent with what is found in the literature, which shows that 25-33% of female trained athletes are iron deficient (Rowland, 2012). Findings from this study extend and advance those from other studies because it a pragmatic program that was implemented in a university athletics department for health and performance monitoring. This distinguishes it from prior publications that were designed a priori and designed as research studies. To our knowledge, only Cowell, et al., 2003 has reported on the influence of pragmatic programs for athletes' iron status. The intervention component of this study reveals an important problem of poor follow-up in taking supplements or undergoing follow-up assessments. For the subset of follow-up individuals, the evidence is in line with the literature, that iron supplementation is effective in improving iron status. The issue arises when athletes do not always take iron supplements. For an iron supplementation study to be effective, pill compliance must occur and then iron supplementation will improve stores. When athletes do not take iron supplements or return for iron supplements, it seems that iron status improvement would be unlikely. Therefore, to be most effective in iron deficiency improvement, one needs a more aggressive intervention strategy to assure pill compliance and intervention compliance to have more follow-up. The study was not designed to provide definitive evidence of noncompliance, though this is seen. Four out of the eight with baseline deficiency who underwent follow up, had gastrointestinal upset. This along with lack of perceived benefit could disrupt pill compliance. A theoretical concern about iron supplementation is iron overload, which has been associated with adverse health effects including iron deposition in the organs which can lead to toxicity of those organs and ultimate failure of those organs leading to cancer, cardiovascular disease, cirrhosis of the liver and other chronic diseases (Chifman et al., 2015). In our supplementation program, we saw no evidence of excessively high iron levels in those who were on iron supplements. However, only athletes with evidence of baseline deficiency were supplemented. In order to avoid iron overload, it would be prudent to continue with an approach like ours (only supplementing athletes with deficiency) and avoiding blanket policies to supplement all athletes. The literature shows that many people who take iron supplementation experience GI upset (Tolkien et al., 2015). This can cause noncompliance of iron supplementation use. When athletes spoke to the physicians of gastrointestinal upset, it was often recommended to take the supplement with food. While this may decrease bioavailability of iron, depending on the food ingested, it was overall believed that some supplemental iron intake was better than none. A potential solution to decrease gastrointestinal upset would be to recommend supplemental iron on a weekly regimen rather than a daily regimen (ZiauddinHyder, 2002). Intravenous iron could also remedy iron deficiency since it has been seen to increase hemoglobin and ferritin stores and is better tolerated. However, it is much more costly and requires IV access which can increase risk for infection and iron overload (Charytan et al., 2005). Another possible solution to noncompliance could be to improve perceived benefit from iron supplementation. Those who were on the cross-country

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team received education on how to take the iron supplement and its benefits. Those who met with the dietitian individually and were on iron supplements, received a similar education. The cross-country team underwent follow up more frequently than the freshmen females. Thirteen out of fifteen underwent follow up (87%) while eight of the forty-nine non-cross-country athletes underwent follow up (16%). This shows how a more aggressive intervention program is more effective in a pragmatic setting. Athletes have busy lives and are juggling a myriad of responsibilities. Early and frequent contact with those who are baseline deficient appeared helpful. If one was compliant, less contact was needed until follow up. Similarly, if symptoms decreased, then follow up could occur less often.

The primary strength of the study was that it was an assessment of a pragmatic iron monitoring and supplementation program, not a formal research study. Therefore, it truly reflects the efficacy of such a program in a real-world Athletic Department setting. However, this also presents with a limitation of poor compliance. Poor compliance could be overlooked in a formal research study where athletes are asked to take iron supplements and are strictly followed and reminded to take the iron supplements. This is not possible in a real-life setting. More support faculty would be required to follow up with athletes about their iron supplementation. Aside from a small sample size, this study has other limitations. Firstly, this study only looked at female freshmen athletes on the cross-country team or who were incoming freshmen for the 2017-2018 academic year. This limits the generalizability to other athlete populations such as the upperclassmen female athletes who have been training more and the male athletes who can be iron deficient as well. Secondly, it was difficult to know how frequently the athletes with baseline deficiency took the iron supplement because it was self-reported. This affects the mean average increase from baseline to follow-up. Additionally, the food frequency questionnaire (FFQ) was only performed on the cross-country team. The FFQ was short which may not account for all sources of iron in the diet, it required the participant to remember food eaten over four weeks, and accurate reporting of frequency and portions can be difficult to recall. Some athletes may not be willing, whether due to taste preference or other, to increase dietary iron, even after education. Thus, iron supplementation would be necessary. In conclusion, results from this study show iron deficiency is an issue in college female athletes as evidenced by 28% of the sample having NAID. Once they were put on iron supplementation, it was seen that they improved, despite poor compliance. Interventions to improve iron status require aggressive intervention strategies to be effective and avoid negative health and performance consequences of iron deficiency.

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