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Prevalence of Iron Deficiency in Female Collegiate Athletes at a Division I Institution

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BACKGROUND: Iron deficiency is widely underdiagnosed in female college athletes and may limit their athletic performance. Routine screening is necessary to identify potential female athletes who might benefit from iron supplementation. A retrospective study on the prevalence of iron deficiency in female collegiate Division I athletes is imperative to bring awareness to the prevailing problem. The objective of this study is to determine the prevalence of iron deficiency in female athletes presenting to a Division I athletic training room for initial health screening evaluation from January 2017 to July 2022.
METHODS: A retrospective chart review was performed for female athletes who presented for initial pre-participation examination health screening to a Division I athletic training room. The data collected included the patients' age, body mass index (BMI), menstrual history, ferritin, and hemoglobin lab values. The primary sports analyzed were swim and dive, soccer, basketball, track and field/cross country, softball, lacrosse, volleyball, high tech, tennis, golf, and cheerleading. Descriptive statistics were used to describe the prevalence of iron deficiency among female athletes and the Student's t-test and Pearson correlation analysis were used to identify any potential risk factors for iron deficiency.
RESULTS: There was a total of 336 participants. The prevalence of athletes with low initial ferritin values under 40 ng/mL at pre-participation examination was 194 (57.74%, n=336). The mean ferritin value at pre-participation examination was 43.18 ng/mL (n=336). Statistical analysis of the other variables collected in this study including BMI, menstrual history and primary sport, showed no significant differences in relationship to initial ferritin levels. Female athletes with low ferritin levels were more likely to receive iron supplementation (p = 8.089 e^{-18}, 95% CI= -31.33142, -20.19980). An increase in ferritin levels was correlated with iron supplementation (p = 0.0217, 95% CI= 1.45825, 18.34014) and hemoglobin levels were higher in female athletes with higher ferritin levels (p = 0.0497, 95% CI=0.00546, 0.14506). Initial ferritin levels were positively correlated with hemoglobin levels (p = 2.402 e^{-11}, 95% CI=0.26962, 0.46399). Statistical analysis showed an increase in ferritin levels with usage of contraception (p = 0.0073, 95% CI= 3.15448, 20.05362).
CONCLUSION: This study's findings represent the importance of screening ferritin levels in all female collegiate athletes regardless of sport, BMI, or menstrual history due to the high prevalence of low ferritin values. There was an increase in ferritin levels with usage of birth control suggesting the need to further evaluate the impact of menstrual history and contraception usage on ferritin and hemoglobin levels. In these authors experience, it is uncommon for institutions to incorporate routine screening measures in place for screening all female athletes with a ferritin value and complete blood count at initial pre-participation examination.

INTRODUCTION

Iron deficiency is one of the most common causes of anemia worldwide and is the most common nutrient deficiency.[1] Anemia due to iron deficiency can cause nonspecific symptoms such as fatigue, dizziness, shortness of breath on exertion and tachycardia.[2] Typical causes includes inadequate nutritional intake of iron.[3] The

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recommended daily amount of iron in premenopausal women is 18 mg/day.[4] Without this daily intake, laboratory findings may trend towards iron deficiency without anemia and may progress to iron deficiency with anemia.[3] Iron deficiency can be characterized into 3 different stages. In the early stage of iron depletion, the organs responsible for storage of iron such as the bone marrow, liver and spleen begin to decrease their iron levels (serum ferritin < 35 ng/mL, hemoglobin [Hb] > 115 g/dl).[5] In stage two, erythropoiesis begins to decrease due to decreased iron in the erythroid portion of the bone marrow (serum ferritin < 20 ng/mL, Hb > 115 g/dl,).[5] Finally, in the last stage of iron deficiency, the hemoglobin levels fall and anemia results (serum ferritin < 12 ng/mL, Hb < 115 g/dl).[5] The populations most affected and susceptible to anemia are young children under 5 years old, women of childbearing age that are actively menstruating and pregnant and postpartum females.[6] Thus, female athletes that are actively menstruating may further contribute to a lower ferritin level compared to non-athlete counterparts. Contraception usage to mitigate heavy menstrual bleeding and regulate the menstrual cycle can increase hemoglobin and ferritin levels.[7]

Athletes have been shown to generally have a decreased hemoglobin level compared to non-athletes possibly related to menstrual loss, increased hemolysis due to increased foot strike and impact, sweating and reduced dietary intake of foods sufficient in iron to maintain adequate iron stores.[8,9] According to a study performed by Parks et. al, at the Division I collegiate level, 2.2% of female athletes had iron deficiency anemia and 30.9% had iron deficiency without anemia.[10] The study concluded an increased prevalence of iron deficiency with or without anemia in female collegiate athletes compared to their male counterparts.[10]

Despite the prevalence of iron deficiency in female athletes, only 43% of collegiate programs report routine screening for iron deficiency among their female participants.[11] Screening of serum ferritin levels is widely used to measure storage of iron in the body and liver.[12] Ferritin level is an important indicator for screening of iron deficiency and was significantly associated with performance times in a study on female rowers.[12] Thus, early identification of iron depletion aids in the initiation of iron supplementation which has been reported to also contribute to increased performance and overall body iron stores.[13] Serum ferritin levels may trend downward during athletes' competitive season, therefore iron supplementation, especially during these seasons can prevent a downward trend in iron levels when compared to no supplementation for athletes with depleted iron status.[14,15]

The prevalence of iron deficiency in female collegiate athletes has not been widely investigated and warrants further research to identify athletes who might benefit from supplementation to maximize athletic performance and improve their well-being. This study aimed to identify the prevalence of iron deficiency in female athletes presenting to a Division I athletic training room for initial health screening evaluation. The effect of variables such as contraception, iron supplementation, body mass index (BMI), sport, and menstrual cycle on iron stores will be analyzed to identify if there is a specific population at highest risk of iron deficiency that should be targeted for screening.

METHODS

Disclosures

This project, Prevalence of Iron Deficiency in Division I Female Collegiate Athletes at a Division I Institution [2105743-1] received exempt review according to the specifications authorized by 45CFR 46.101 and 21 CFR 56.110 by the Edward Via College of Osteopathic Medicine Institutional Review Board (VCOM IRB, 2023-157). No funding was necessary for the completion of the study. As a retrospective review, there was no necessity for clinical trial registry and informed consent was deemed exempt and approved by the VCOM IRB. There was no patient or participant compensation provided.

Subject Population

All female collegiate I athletes who presented to a Division I athletic training room from January 2017 to July 2022 for an initial pre-participation evaluation (PPE) and received a ferritin lab value were included in this study. The routine protocol for evaluating athletes with low ferritin values is shown in Figure 1. The athletes' name, date of birth and ferritin value and date of blood draw were recorded in a password-protected Excel spreadsheet. These athletes were cross-referenced in the corresponding electronic medical record, Sportsware Online, to obtain additional clinical metrics including the athletes' height, weight, date of evaluation, and menstrual history, The primary

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sport was documented which included swim and dive, soccer, basketball, track and field/cross country, softball, lacrosse, volleyball, high tech, tennis, golf, and cheerleading.

Exclusion Criteria

A total of 36 female athletes who did not have a ferritin level drawn at the time of their initial examination were excluded from the study. Additional exclusion criteria include female athletes without hemoglobin values performed at PPE and those with no follow up ferritin values. Regarding athletes' menstrual history, 11 female athletes did not self-report an age of menarche onset and were excluded. A single case of a self-reported age of menarche was reported as one year of age which was excluded due to the inaccuracy of this value. Thirty-seven female athletes that reported irregular cycle lengths or those who reported amenorrhea were excluded. The athletes that did not report contraceptive choice or lack thereof were excluded. For the additional variable analyzed such as BMI, the athletes without a measured height or weight were excluded.

Data Collection

Ferritin levels for a total of 336 female athletes of 372 who presented for initial evaluation were included in the study. The prevalence of ferritin values under 40 nanograms per milliliter (ng/mL) according to the Division I Institution protocol was analyzed. The average ferritin levels at initial PPE were calculated . The prevalence of those with low hemoglobin values under 12 grams per deciliter (g/dl) and average hemoglobin levels at initial PPE was analyzed.

Ferritin levels were drawn annually, unless the athlete became symptomatic. For those athletes requiring an iron supplementation prescription of oral ferrous sulfate 325 mg once daily, repeat follow up ferritin labs were drawn 3-6 months after initiation. A change in ferritin levels was determined for each female athlete using the latest ferritin level drawn compared to the initial ferritin level performed at the PPE.

Each athlete filled out a questionnaire at initial PPE regarding medical history, family history, surgical history, and medications. The questionnaire included a separate menstrual history section that including age of menarche onset, typical menstrual cycle length, last menstrual period, number of periods per year, use of contraception and type, and history of a pelvic exam/pap smear. The contraception choices were categorized as no contraception, oral contraceptive pills, or alternative forms of contraception such as IUD or Nexplanon, Depo-Provera injection, and Nuva ring.

The athletes who reported a range of days for the cycle length, the lowest value in days was used to calculate the prevalence of polymenorrhea and the highest value in days was used to determine the prevalence of oligomenorrhea. The reported cycle lengths were considered a normal cycle for 21–35 day cycles. The female athletes that reported cycle length in months or weeks was converted into days. The prevalence of those with oligomenorrhea was defined as a cycle length > 35 days. The prevalence of those with polymenorrhea was defined as a cycle length < 21 days.

Statistical Analysis

Data analysis was performed using the Excel data analysis tool pack as well as R v4.1.0. A chi-squared test was used to analyze low ferritin levels (< 40 ng/mL) with low hemoglobin levels (< 12 g/dl). Student's t-test was used to compare ferritin levels between categorical risk factors. Pearson's correlation analysis was used to determine the association between ferritin levels and continuous risk factors. A single factor ANOVA was performed for the athletes' primary sport in comparison to initial ferritin values.

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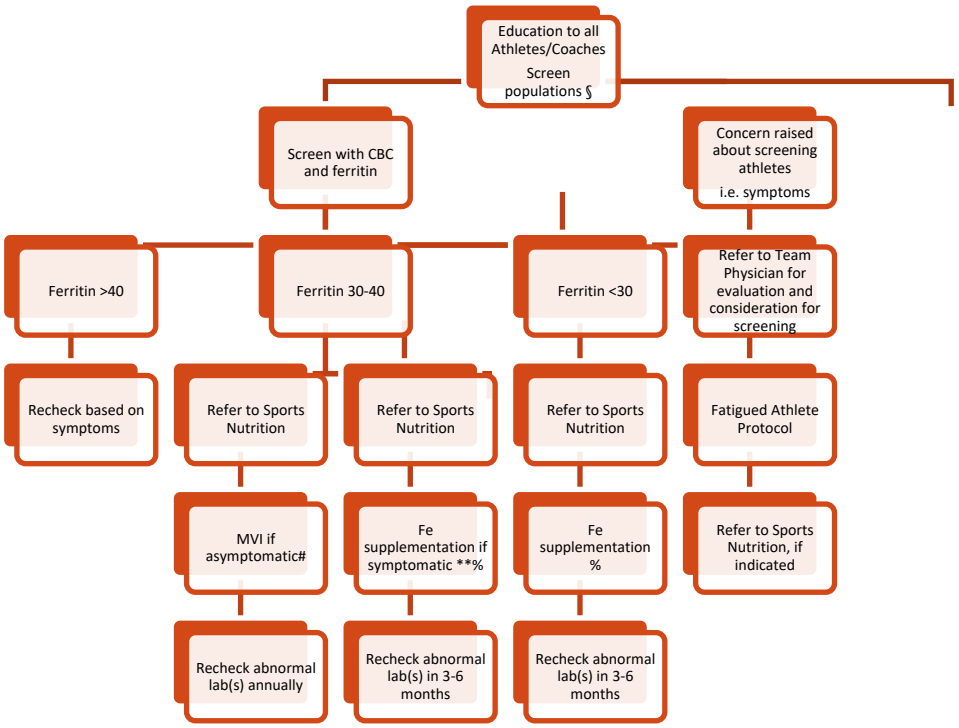

Figure 1. Ferritin screening protocol and treatment plans at a Division I institution

RESULTS

Average age of the 336 participants in the study at initial PPE was 18 years of age (Table 1). The prevalence of athletes with low initial ferritin values under 40 ng/mL at pre-participation examination was 194 (57.74%, N = 336). The mean ferritin value at pre-participation examination was 43.18 ng/mL (n=336). The prevalence of athletes with low initial hemoglobin values under 12 g/dl at pre-participation examination was 30 (9.84%, N = 305). The mean hemoglobin value at pre-participation examination was 13.09 g/dl (N = 305). ANOVA testing showed there was no significant relationship between primary sport and initial ferritin levels (p > 0.05, N = 334). The percentage of athletes participating in each primary sport is displayed in the demographic Table 1 along with average initial ferritin values for each sport (Table 2).

As seen in Figure 2, initial ferritin levels were positively correlated with hemoglobin levels (p = $2.402e^{-11}$, 95% CI=0.26962, 0.46399), but did not significantly differ by sport (Table 2). Hemoglobin levels were higher in female athletes with higher ferritin levels (p-value = 0.04971, 95% CI=0.00546, 0.14506). There was no significant correlation between age of menarche onset (years), cycle length (days) or BMI with initial ferritin levels. There was no significant difference in the average initial ferritin levels for female athletes using contraception. Five female athletes reported polymenorrhea (< 21 day cycle, 1.76%, N = 284). Twenty-one female athletes reported oligomenorrhea (> 35 day cycle, 7.09%, N = 296). A two sample T-test showed there was no significant effect of polymenorrhea on ferritin levels (p-value > 0.05). Likewise, a two sample T-test showed there was no significant effect of oligomenorrhea on ferritin levels (p-value > 0.05). There was no significant correlation between the two variables of cycle length (days) and initial ferritin level (Figure 2).

Figure 3 shows the results of the Pearson correlation that shows an increase in ferritin levels is correlated with iron supplementation (p = 0.0217, 95% CI= 1.45825, 18.34014). There is a strong association between an increase in ferritin levels with usage of birth control (p = 0.0073, 95% CI= 3.15448, 20.05362).

Two hundred seventeen female athletes recorded receiving a prescription for oral ferrous sulfate 325mg once daily supplementation (N = 336). There were 119 female athletes who did not

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take iron supplementation throughout the duration of the study (N = 336). The average change in ferritin values for those receiving supplementation was 17.20 versus the average change in ferritin values for those not on supplementation was 7.05 (Table 3).

Table 1. Demographics of athletes at initial PPE

Primary Sport	*# Participants*	*Prevalence in study group*
Track/Cross Country	*78*	*23.21%*
Lacrosse	*55*	*16.37%*
Swim & Dive	*46*	*13.69%*
Soccer	*36*	*11.01%*
Basketball	*35*	*10.42%*
Softball	*30*	*8.93%*
Volleyball	*27*	*8.04%*
Tennis	*20*	*5.95%*
Golf	*5*	*1.49%*
High Tech	*2*	*0.60%*
Cheer	*1*	*0.30%*
BMI	*# Participants*	*Prevalence in study group*
Underweight <18.5	*11*	*3.36%*
Normal 19.5-24.99	*275*	*84.10%*
Overweight 25-29.99	*35*	*10.70%*
Obese >30	*6*	*1.83%*
Age at PPE (years)	*# Participants*	*Prevalence in study group*
16	*1*	*0.30%*
17	*35*	*10.45%*
18	*230*	*68.66%*
19	*30*	*8.96%*
20	*21*	*6.27%*
21	*12*	*3.59%*
22	*5*	*1.49%*
23	*1*	*0.30%*

BMI, Body Mass Index; PPE, pre-participation evaluation

Table 2. Average initial ferritin level by sport

Sport	*Average Ferritin Value (ng/mL)*
Track/Cross Country	*44.8*
Lacrosse	*40.5*
Swim & Dive	*48.5*
Soccer	*42.2*
Basketball	*48.4*
Softball	*36.0*
Volleyball	*33.6*
Tennis	*52.3*
Golf	*28.8*
High Tech	*45.0*
Cheer	*30.0*

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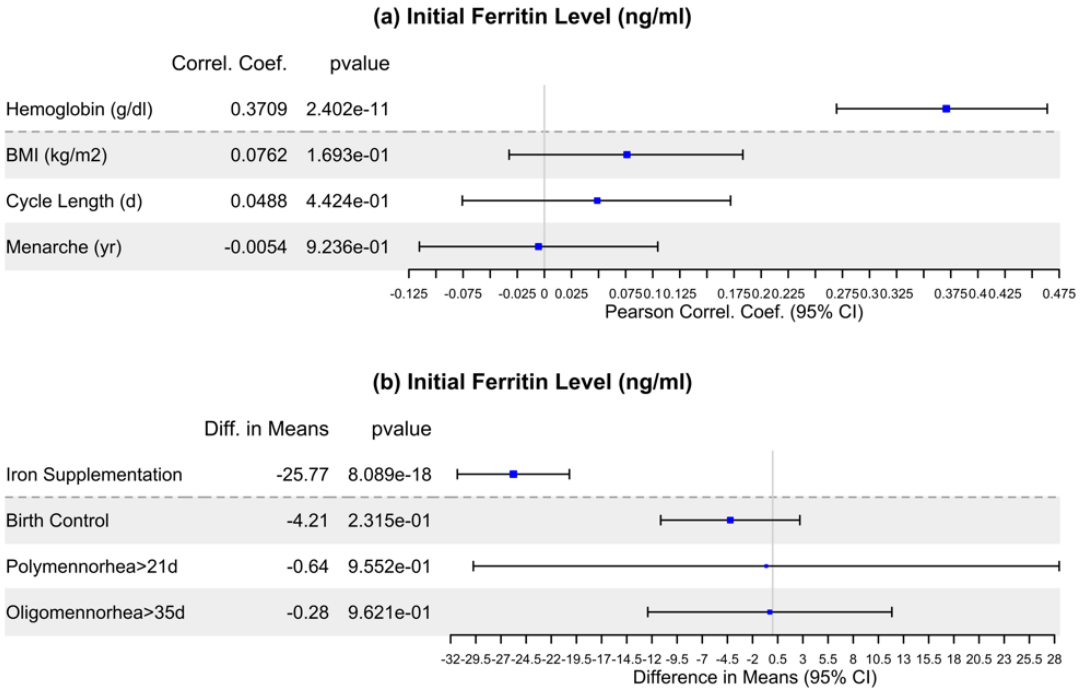

Figure 2. Pearson correlation of initial ferritin level in relationship to hemoglobin level, BMI, cycle length (days), and age of menarche onset (a). Two sample t-test for initial ferritin levels associated with iron supplementation, use of contraception, and irregular menstrual cycles (<21 days = polymenorrhea; > 35 days = oligomenorrhea) (b). *BMI, body mass index*

Table 3. Mean ferritin level at PPE in all female athletes in the study. The average changes in ferritin levels with and without iron supplementation

	Ferritin Level (ng/mL)	***Average Change in Ferritin***
Average Initial Ferritin Level in all athletes	43.2 ng/mL	--
Average Ferritin level in females with low ferritin prior to iron prescription	23.4 ng/mL	17.2 ng/mL
Average Follow up Ferritin level in females with low ferritin after iron prescription	40.7 ng/mL	
Average Ferritin level in females with normal ferritin at initial PPE	48.4 ng/mL	7.1 ng/mL
Average Follow up Ferritin level in females not requiring iron prescription	55.0 ng/mL	

PPE, Pre-participation evaluation

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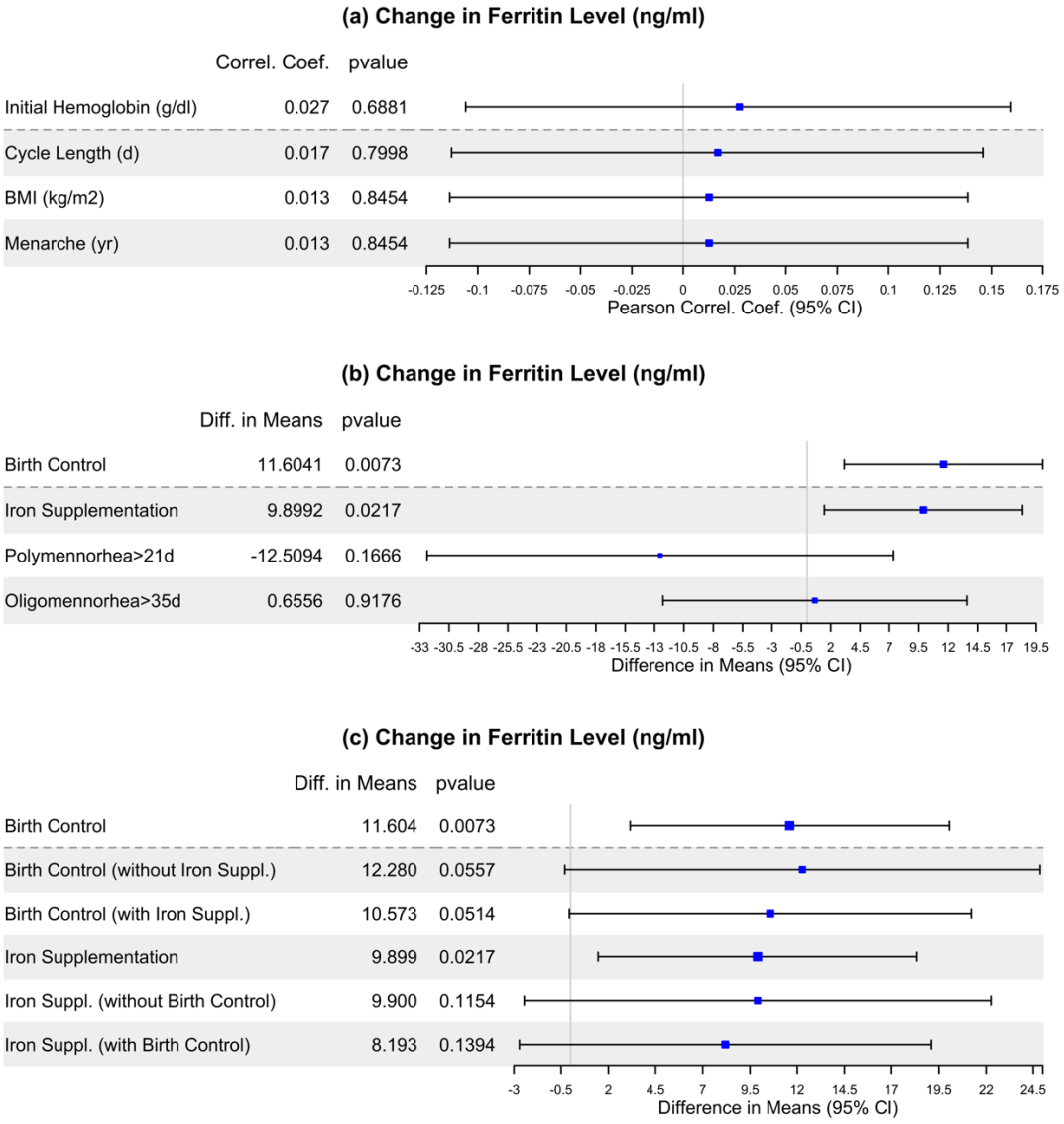

Figure 3. Pearson correlation for a change in ferritin levels in relation to hemoglobin level, BMI, cycle length (days), and age of menarche onset (a). Two sample t-test of the association of a change in ferritin levels with birth control, polymenorrhea, oligomenorrhea (b), birth control with and without iron supplementation, iron supplementation, iron supplementation with and without birth control (c)
BMI, Body Mass Index

DISCUSSION

In this study of female collegiate Division I athletes, 57.74% of athletes had documented ferritin levels below 40 ng/mL at PPE with a mean ferritin level of 43.18 ng/mL. The upper limit ferritin value used in this study to categorize females with iron depletion was set to 40ng/mL, as the Division I screening protocol uses this value to refer females to nutritional counseling to prevent a trending decrease in ferritin values and to maximize athletes' dietary intake before oral supplementation must be considered. Previous studies performed on female athletes and iron depletion show a range in prevalence of iron store depletion to range from various ranges from 18% to 57%.[9] The variability in the prevalence of iron storage depletion in these studies can be contributed to the differing cut-off values used to categorize iron depletion.[9] In a study

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performed by Koehler et. al, the prevalence of iron depletion in various sport athletes was reported to be 57%.[16] This value compares with the results in this current study, as Koehler et. al. used a cut-off value of 35 ng/mL to define iron depletion.[16] The studies that report a much lower prevalence of iron depletion, such as the study by Milic et al. with a report of 18% iron depletion in various sport athletes, may be contributed to a much lower cut-off value for ferritin levels to be considered iron deficient.[17] The cut off value set by Milic et al. was 22 ng/mL, and therefore fewer athletes were included and categorized as iron deplete.[17]

It is necessary to raise the cut-off ferritin value to screen for iron deficiency, such as in this present study, to a value such as 40 ng/mL to identify athletes who will benefit from nutritional education prior to the implication of iron supplementation. Iron supplementation in young female athletes may have poor compliance for various side effects including gastrointestinal upset and constipation. Thus, nutritional education on increasing dietary iron intake is first line and can be implemented prior to the need of iron supplementation once the ferritin levels fall to a critical value less than 40 ng/mL. As seen in Figure 1, the protocol at Virginia Tech for ferritin screening and evaluation uses 40 ng/mL as a proactive measure to control iron levels. For the female athletes who necessitated the need for iron supplementation, statistical analysis showed that an increase in ferritin levels is correlated with iron supplementation. This increase in ferritin values is essential to improve athletic performance and avoid furthering the stages of iron depletion and ultimately leading to iron deficiency anemia. Statistical analysis suggests that hemoglobin levels are higher in female athletes with higher ferritin levels, and thus early supplementation is critical in treatment and screening protocols for collegiate female athletes.

Contraception usage was recorded in this study at initial PPE. Statical analysis showed a strong association between an increase in ferritin levels with usage of birth control (p = 0.0073, 95% CI= 3.15448, 20.05362). This may be in part explained by prolonged usage of contraception from time of initial ferritin level collection to the later ferritin level collection. The female athletes on prolonged usage of a form of contraception may provide controlled menstrual cycles, a decrease in the loss of iron from active bleeding during menses, and therefore lead to an overall increased ferritin value compared to their female athlete counterparts not using contraception. There was no relationship between initial ferritin levels with contraception, so it is believed that this continued use of birth control contributes to the significance of a change in ferritin levels. A limitation to this finding is there was no follow up on contraception and to whether the female athlete continued birth control usage from their initial evaluation and the birth control compliance at the follow up ferritin collections. For those who reported contraception usage, the start date of the birth control was also not recorded. Thus, it is of interest in future studies whether the total length of contraception usage benefits overall ferritin levels.

Statistical analysis of the other variables collected in this study such as BMI, menstrual history, and primary sport showed no significant differences in relationship to initial ferritin levels or a change in ferritin values. These findings correspond with results reported in various studies such as the study by Gropper et. al. that reports no significant difference in laboratory iron studies among different athletic teams.[3] The clinical significance of these findings contributes to the importance of screening all female collegiate athletes' ferritin levels regardless of BMI, menstrual history, or sport. The factors that were analyzed in this study does not place a specific population at higher risk of deficient iron levels and thus all athletes should be targeted for screening.

Although more than half the athletes had low ferritin values, less than 10% (9.84%) of the female athletes in this study had iron deficiency anemia with a hemoglobin value under 12 g/dl. The average hemoglobin level for the female athletes at screening examination was 13.09 g/dl, which is within the normal range. This finding represents the importance of screening ferritin values, specifically in female collegiate athletes, as a complete blood count is not sufficient to diagnose iron deficiency without anemia. Few institutions include routine screening measures in place for screening all female athletes with a ferritin value and complete blood count at initial pre-participation examination (Figure 1).

There are various limitations to be considered for this present study. For those who a ferritin value was drawn, a complete blood count result could not always be found in the electronic medical record and may not have been drawn at the same time. This led to decreased hemoglobin values compared to the number of female athletes with ferritin values identified. The paper charts were scanned into the

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electronic medical record, so it must be considered that there is chance of human error of incorrectly scanning in records to the correct patient chart. For the female athletes who were recommended initiation of iron supplementation, the compliance with the oral ferrous sulfate was not determined and may contribute to differing ferritin values. The female athletes' menstrual history was completed by the athlete themselves and the questions may have been misinterpreted as the responses were answered in free text. Thus, future studies may be able to further determine the impact of the prolonged or heavy menstruation on initial ferritin levels, and compliance of iron supplementation regimen could be investigated.

CONCLUSION

This study's findings represent the importance of screening ferritin levels in female collegiate athletes. Institutions could consider incorporating routine screening measures in place for screening all female athletes with a ferritin value and complete blood count at initial pre-participation examination. After statistical analysis suggesting that an increase in ferritin levels is correlated with iron supplementation (p = 0.0217, 95% CI= 1.45825, 18.34014) and that hemoglobin levels are higher in female athletes with higher ferritin levels (p-value = 0.04971, 95% CI=0.00546, 0.14506), a protocol must be in place at collegiate institutions for screening and treatment of female athletes with iron deficiency with or without anemia. The findings of an increase in ferritin levels with usage of birth control (p = 0.0073, 95% CI= 3.15448, 20.05362) necessitates the need to further evaluate female athletes' menstrual cycles and contraception usage and its impact on ferritin and hemoglobin levels. This study's findings represent the importance of screening ferritin levels in all collegiate athlete programs regardless of sport, BMI, or menstrual history due to the high prevalence of low ferritin values across many variables.

Conflict of Interest Statement

The authors declare no conflicts of interest with the contents of this study.

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