

## A. Define the problem

**The majority of females (specifically endurance athletes) do not get enough iron in their regular diet to support healthy levels in their blood. How can I design a plan for sufficient iron intake that is easiest to follow and absorbs the iron that is needed?**

Iron deficiency is the most common nutritional disorder. It affects 20-25% of the world's population, the majority of that being women (Conlon). Some of the highest risk groups for iron deficiency are women, endurance athletes, and young people who are still growing ("Iron | The Nutrition Source | Harvard T.H. Chan School of Public Health"). This creates a perfect storm for young female endurance athletes like myself who are very likely to not get the iron we need to be healthy and strong. Getting the appropriate amount of iron needed to sustain a female athlete or non-athletic female even, usually takes some purposeful nutrition choices and work. Adequate iron levels are not something that is often discussed in normal everyday life, but it is so important to being a healthy and strong athletic female.

### **Why is iron so important?**

Iron is required in the body to make hemoglobin, which is a protein in your red blood cells that is responsible for carrying oxygen from your lungs throughout your body (Frame). Iron is also a part of the protein myoglobin which carries and stores oxygen in muscle tissue. If iron in the body is too low you can experience fatigue, loss of concentration, weakness, rapid heart rate, and shortness of breath among other symptoms ("Iron | The Nutrition Source | Harvard T.H. Chan School of Public Health"). Iron is also a vital mineral to maintain a healthy immune system so someone with low iron may get sick a lot and/or have frequent infections (Quinn).

### **Why are females and endurance athletes so susceptible to iron deficiency?**

Endurance athletes have increased iron loss up to as much as 70% when compared to people who are not endurance athletes. Endurance athletes lose more iron through sweating and quicker breakdown of red blood cells (example: foot strike when running leads to destruction of red blood cells in foot) (Gaudiani). Additionally, when you aerobically exercise your body loses plasma (the liquid part of your blood) so your body adapts to that by conserving water and salt. This results in an overexpansion of plasma production which is much greater than the production of red blood cells which causes the hemoglobin in your blood to be diluted. In order to make more hemoglobin your body requires iron which can then deplete your body of its iron ("Home"). This all makes endurance athletes very susceptible to iron deficiency, but females are even more at risk because their monthly menstrual cycle causes them to lose blood which depletes their red blood cell supply.

## **Criteria & Constraints:**

### Criteria:

- Something that is easy to follow and fit into a daily routine
- Something that doesn't make you feel sick
- Provides adequate amount of iron for a female non-vegetarian athlete

### Constraints:

- Can't be too expensive, be accessible to all people (shouldn't add more than 15\$ per week onto the regular grocery bill.)
- Can't take more than ½ an hour to prepare/implement a day
- Is no more than 50% supplements

## **B. Design Solution**

### **How much iron is a female athlete going to need per day to stay healthy?**

The recommended amount of iron per day for the general population is 8.1 mg, however it is recommended that premenopausal, active, females get 18 mg per day (DellaValle). Ferritin levels (amount of stored iron in body) can be tested and should ideally be above 35 ng/mL for female athletes (Pritchett).

### **Iron absorption:**

Iron is a low bioavailable mineral, which means that the small intestine has a difficult time absorbing it. This is part of why people are so likely to be deficient in iron. You can be eating a well balanced diet and still not meeting your iron needs because even though it is so vital to our health, it is a very tricky mineral for our bodies to absorb and store in a way that makes it accessible to use.

There are two types of dietary iron: heme and non-heme iron. Heme iron is much more absorbable.

When you eat something with heme iron in it your body will absorb up to 40% of the iron in it. In contrast to this, non-heme iron is much less absorbable, usually having about a 2-20% bioavailability.

Heme iron is found in meats and seafood, whereas non-heme iron is in certain plant-based foods (Marcin and Marengo).

Certain foods/food compounds can increase/maximize iron absorption when consumed together. These include:

- Ascorbic acid (vitamin C)
- Malic acid
- Citric acid
- Fermented/germinated foods

In contrast to that, other foods/food compounds can block/reduce the absorption of iron if eaten together. These items include:

- Calcium
- Phytic acid
- Tannins
- Polyphenols

(“Dietary promoters and inhibitors of iron absorption. | Download Scientific Diagram”)

### **What about iron supplements?**

Getting iron through diet is ideal because bodies are best equipped to absorb nutrients through food. However, when iron is low it is sometimes very difficult to get the required amount of iron simply through diet because it becomes complicated and difficult to keep track of and maintain. This is where iron supplements can be very helpful. They are easy to take (simply swallow a capsule and you're good), available in different doses so you can easily personalize based on the need, and they get you the iron you need in 10 seconds or less and then you're good for the day. However there are also cons to taking iron supplements. Iron from a capsule is not as easy for your body to absorb and should be taken with a vitamin C rich drink (i.e orange juice) to maximize absorption. Iron supplements can also cause temporary stomach discomfort such as constipation and nausea. Iron is toxic when taken in too large a dose so you always want to make sure you are taking no more than prescribed (“Taking iron supplements”).

I believe iron supplements play an important role in remedying iron deficiency but they have to be used wisely. A recent study showed strong data that taking a higher dose of iron (in the form of a supplement) on alternating days results in higher iron absorption and less gastrointestinal side effects than if a lower iron supplement was taken daily (“Iron absorption from supplements is greater with alternate day than with consecutive day dosing in iron-deficient anemic women”).

This aligns with my personal experience with taking iron supplements and I think this is a scientifically backed and effective way to get enough iron while not harming yourself with too much and/or side effects.

### **Foods with high iron content:**

#### **Heme iron**

- Liver (9 mg per 2 ½ oz)
- Oysters or mussels (5.5 mg per 2 ½ oz)
- Lamb or beef (2.5 mg per 2 ½ oz)
- Canned sardines (2 mg per 2 ½ oz)
- Clams (2.1 mg per 2 ½ oz)
- Tuna (1.2 mg per 2 ½ oz)

#### **Non-heme iron**

- Dark Chocolate (12 mg per bar)

- Cheerios (8 mg per 1 cup)
- Soybeans (6.5 mg per  $\frac{3}{4}$  cup)
- Beans or lentils (4 mg per  $\frac{3}{4}$  cup)
- Pumpkin seeds (4.7 mg per  $\frac{1}{4}$  cup)
- Molasses (3.6 mg per 1 tbsp)
- Spinach (3.4 mg per  $\frac{1}{2}$  cup cooked)
- Tofu or edamame (2.4 mg per  $\frac{3}{4}$  cup)
- Chickpeas (2.2 mg per  $\frac{3}{4}$  cup)
- Potatoes (1.9 mg per 1 medium)
- Bagels (1.9 mg per  $\frac{1}{2}$  bagel)
- Eggs (1.4 mg per 2)
- Oats (1.4 per  $\frac{3}{4}$  cup cooked)
- Sunflower seeds (1.2 mg per  $\frac{1}{4}$  cup)

("Iron in Foods")

**Foods to best maximize/increase iron absorption:**

- Citrus (lemon, grapefruit, kiwi, orange, limes)
- Bell peppers
- Strawberries
- Tomatoes
- White potatoes
- Brussel sprouts
- Broccoli
- Cabbage
- Apples
- Bananas
- Cherries
- Carrots
- Peas
- Beans
- Sauerkraut
- Kimchi
- Cantaloupe
- Kombucha

(Binu)

("Vitamin C | The Nutrition Source | Harvard T.H. Chan School of Public Health")

### **Foods to avoid eating with iron rich foods:**

- Milk
- Cheese
- Yogurt
- Ice cream
- Coffee
- Tea

### **Original Possible Solution Ideas:**

1. Taking an Iron supplement everyday

I ended up not considering this solution too much because while it is an extremely easy way to get adequate amounts of iron daily, iron supplements can cause uncomfortable side effects when taken too often and can have complications absorbing in the body. I have taken an iron supplement daily before and it caused a lot of issues in my gut and didn't actually make my iron go up that much. I also quickly found a study in my research that showed results that iron supplements are actually more effective when taken every other day ("Iron absorption from supplements is greater with alternate day than with consecutive day dosing in iron-deficient anemic women").

2. Tracking iron in all food throughout the day to aim to get enough by the end of the day

Another solution I came up with that originally seemed like it would be easiest on the body was to just track all the iron in your food throughout the whole day and mindfully eat iron-rich foods when you need them. This seemed like a good idea because iron is easier to absorb and gentler on the body when it is ingested through food. However, I have tried this as well and it is a huge mental task to try and remember, add up, and figure out how to incorporate more iron everyday. With all the things life asked of me to focus on everyday I would find that most days my iron intake would be disregarded because it didn't take enough priority in my mind over other deadlines and commitments. The lack of structure did not work.

### **Solution**

#### **Weekly iron plan for female athlete:**

**(alternating days: day 1 follow plan A, day 2 follow plan B...etc)**

Day A: (Days 1, 3, 5, 7) Take 1, 25 mg iron capsule (Solgar Gentle Iron, 16.60\$, 180 capsules)

Day B: (Days 2, 4, 6) Plan A carries over 7 mg for Plan B days (25 mg-18 mg = 7 mg) so only 9 mg needed on Plan B days.

Get iron through breakfast (exchange format.)

*The Optimal Iron Plate:*



Pick one from each category to make a plate that gets at least 9 mg + foods to aid absorption:

Category 1 (main source of iron):

- 1 cup of cheerios
- 1 cup of beans
- 5 oz of lamb or beef
- 1/3 cup of pumpkin seeds
- 2 tbsp of molasses

Category 2 (secondary source of iron):

- 3 oz of tuna
- 1 bagel
- 2 medium potatoes
- 1 cup of cooked oats
- 1/2 cooked spinach
- 1/4 cup sunflower seeds

Category 3 (iron absorption aid):

- ½ orange or grapefruit
- 1 kiwi
- 1 banana
- 1 cup strawberries or cherries
- ½ cup tomatoes
- 1 cup cantaloupe
- 1 cup bell pepper or broccoli

Suggested meal ideas (to get needed iron in as breakfast on B days):

- ★ 1 cup Cheerios with non-dairy milk, ¼ cup sunflower seeds, and strawberries (9.2 mg of iron)
- ★ 1 cup oatmeal with 2 tbsp molasses and a banana (9.1 mg of iron)
- ★ ¾ cup Beans, ½ cup spinach, and tomato scramble with 2 eggs (8.8 mg of iron)
- ★ 1 Bagel with 1 tsp molasses, banana, peanut butter, and ¼ cup pumpkin seeds (9.7 mg of iron)
- ★ 2 Fried potatoes/hash browns with bell peppers and 5 oz ground beef (8.8 mg of iron)

### How does this plan fit the Criteria & Constraints?

Criteria:

- Something that is easy to follow and fit into a daily routine

This plan should be relatively easy to follow and shouldn't take too much time because either you are simply taking a supplement or eating breakfast. I could see how the B days could become complicated to always have to think about, make, and eat a breakfast that has the right amount of iron and other absorption helping nutrients. I will test this out and perhaps improve this in section C.

- Something that doesn't make you feel sick

As the results of the study from the *Haematologica* study discussed, there is researched evidence that taking iron supplements on alternating days is shown to significantly reduce any gastronomical side effects. I implemented this practice in my plan to help meet this criteria while also ensuring iron needs were met everyday.

- Provides adequate amount of iron for a female non-vegetarian athlete

This plan meets the amount of iron recommended for a female athlete's daily intake (18mg). It spreads it out in a scientifically supported way so as to meet other criteria and reduce side effects. Some of it is through non-vegetarian items so this plan would not be suitable for a vegetarian athlete.

Constraints:

- Can't be too expensive, be accessible to all people (shouldn't add more than 15\$ per week onto the regular grocery bill.)

This plan shouldn't be too expensive because all of the food items are regular products that can be a part of a normal grocery bill and the ingredients can be used at other mealtimes. The supplements are

16.60\$, but it gives you a jar of 180 capsules of which only 4 are taken a week. This breaks down to only about 37 cents a week.

- Can't take more than 1/2 an hour to prepare/implement a day

Some of the suggested breakfast ideas on B days can be prepared and eaten in 1/2 an hour easily and others could possibly fit into a 1/2 hour if rushed. I am going to address this in section C because this is a constraint that could be improved to create a less rushed and stressful routine.

- Is no more than 50% supplements

This plan is 50% supplements because the supplement is taken on alternating days so it fits this criteria.

### C. Improve Solution

While the iron supplement part of the plan is quite easy and quick to implement, it can be difficult -especially with a busy schedule like young athletes have- to prepare and eat a whole breakfast that gets in the amount of iron needed. A lot of days there is not much time or energy delegated to the mornings to relaxedly make and eat a properly iron rich breakfast and it ends up in some B days getting missed. I was struggling to make and eat a properly iron-rich breakfast before school while also getting enough sleep, getting all my stuff together, and being on time. While I knew iron was important, it was very easy in the mornings for it not to take priority.

My idea on how to improve this solution is to find an iron rich, easy to make, baked good that could be prepared once a week and then just grabbed and eaten on the go on B days. It needs to have enough iron (9 mg on B days) and not be too difficult to make (prep time of 1/2 or less) so that it won't be too much of a task to make time to do once a week. I am also a supporter of eating delicious, nourishing food because our body absorbs nutrients better when it is enjoying what it is eating. These should be yummy!

### Recipe Ideas for *The Iron Bomb*:

#### Variation 1

<https://lifeisnoyoke.com/iron-bites/>

- molasses - 2 Tbsp.
- dates (pitted) - 6 whole
- apricots (dried) - 3/4 cup
- dark chocolate (bar or chips) - 1/4 cup
- flax seeds - 1/4 cup
- pumpkin seeds - 1/4 cup
- cashews (raw) - 1/4 cup
- almonds (raw) - 1/4 cup
- oats (rolled) - 3/4 cup (+1/4 cup for garnish)
- coconut (flaked unsweetened) - 1/4 cup (+1/4 cup for garnish)



This recipe contains 29.2 mg of iron. If made into 8 balls and then 2 balls eaten on B days about 7.3 mg of iron would be acquired. These should be eaten with a glass of vitamin C containing juice (i.e orange) to increase absorption.

### Variation 2

<https://blog.withextraveg.net/iron-rich-chocolate-protein-balls/>

- > 1 cup Raw Cashews
- > 1 cup Pumpkin Seeds
- > 1/4 cup Sesame Seeds
- > 1/4 cup cocoa powder
- > 1 cup dates pitted

This recipe contains 33.6 mg of iron. If made into 8 balls and then 2 balls eaten on B days about 8.4 mg of iron would be acquired. Again, these should be eaten with a vitamin C rich food for maximal absorption.

(Cudmore)

### Variation 3

#### Recipe of my design!

Iron rich balls :)

Ingredients:

- > 1/4 cup cocoa powder
- > 1/4 cup sesame seeds
- > 1/4 pumpkin seeds
- > 4 tbsp molasses
- > 1/4 cup peanut butter
- > 1/4 cup oats

This recipe contains about 29 mg of iron. If made into 6 balls and then 2 eaten on B days it would be about 9.6 mg of iron. Vitamin C to be taken with.

Votes for which *Iron Bomb* tastes best (testing done on pilot students voting on their favorite after tasting all 3):

V1	V2	V3
5	7	6 1/2

#### Selecting an *Iron Bomb* & finding a final solution:

The second variation of *Iron Bombs* got the most votes by 1/2 of a vote on being the most delicious. This variation has the least ingredients and they took slightly less time to make than the others. The recipe

has the most iron out of the 3, but the way I have it divided the balls have 1.2mg less iron than variation 3 and 0.6mg less than they need to have to meet the adequate iron criteria. My solution to this is to add ¼ cup of chocolate chips to the recipe which will add 4 mg of iron to the recipe. This means there will now be 37.6 mg of iron in the recipe and 9.4 mg per 2 balls.

#### ***New Iron Bomb recipe (Variation 4)***

- 1 cup Raw Cashews
- 1 cup Pumpkin Seeds
- ¼ cup Sesame Seeds
- ¼ cup cocoa powder
- 1 cup dates pitted
- ¼ cup dark chocolate chips

My final solution to get enough iron as a female athlete is to follow an A/B day plan like I had proposed in part B, but to replace the *Optimal Iron Plate* with Variation 4 *Iron Bombs*.

#### **Final weekly iron plan for female athlete:**

**(alternating days: day 1 follow plan A, day 2 follow plan B...etc)**

Day A: (Days 1, 3, 5, 7) Take 1, 25 mg iron capsule (Solgar Gentle Iron)

Day B: (Days 2, 4, 6) Eat 2, V4 *Iron Bombs*

#### **Final discussion on criteria/constraints**

I am replacing the *Optimal Iron Plate* because it didn't meet all the criteria and constraints discussed in Part B. The two criteria/constraints the *Iron Plate* failed to meet were (1) Something that is easy to follow and fit into a daily routine, (2) Can't take more than ½ an hour a day.

The *Iron Bombs* are a better solution because they adequately meet all the criteria and constraints. The *Iron Bombs* combined with the iron supplement and used in A/B day format, this plan provides a strong, effective, and adequate solution to the issue and satisfies all the criteria and constraints put in place.

#### **Criteria & Constraints Revisited**

- Something that is easy to follow and fit into a daily routine

This plan should be easy to follow and shouldn't take too much time because either you are simply taking a supplement or munching on 2 iron bombs at whatever time is best for you.

Criteria:

- Something that doesn't make you feel sick

As the results of the study from the *Haematologica* study discussed, there is researched evidence that taking iron supplements on alternating days is shown to significantly reduce any gastronomical side effects. I implemented this practice in my plan to help meet this criteria while also ensuring iron needs were met everyday. Additionally I tested out the iron bombs on 18 people and they were reported to be delicious and did not make anyone sick.

- Provides adequate amount of iron for a female non-vegetarian athlete

This plan meets the amount of iron recommended for a female athlete's daily intake (18mg). It spreads it out in a scientifically supported way so as to meet other criteria and reduce side effects. This plan could even be used if you were vegetarian.

**Constraints:**

- Can't be too expensive, be accessible to all people (shouldn't add more than 15\$ per week onto the regular grocery bill.)

This plan shouldn't be too expensive because all of the food items used in the Iron Bombs are regular products that can be a part of a normal grocery bill and the ingredients can be used at other mealtimes. The supplements are 16.60\$, but it gives you a jar of 180 capsules of which only 4 are taken a week. This breaks down to only about 37 cents a week.

- Can't take more than 1/2 an hour to prepare/implement a day

Both taking a supplement and eating 2 Iron Bombs take much less than 1/2 hour a day. The Iron Bombs can be prepared once a week so that they are ready to go for the rest of the week and the prep/time to make is only about 15 minutes.

- Is no more than 50% supplements

This plan is 50% supplements because the supplement is taken on alternating days so it fits this constraint..

**How can this information be applied to a current, real-life situation?**

I am a 16 year old female endurance athlete so I fall right into the category of those most at risk for iron deficiency. Additionally, I have some history with disordered eating which can be a further cause of imbalance in nutrients in the body. I had the iron levels in my blood tested in early July 2022 because I have been missing my period and healthy iron levels play a role in a healthy menstrual cycle.

In a regular, non-athlete, ferritin (stored iron) levels should be between 10-20 ng/mL. In an athlete a healthy amount of ferritin is between 40-50 ng/mL (Benjamin). My ferritin from July showed a level of 8 ng/mL and that is with me being a cross-country athlete..

This means that my iron is very low and it is crucial that I find a way to increase my iron in order to have good performance and overall health. This project is personal in the sense that it literally applies to my life and I will actively use and experiment with the solutions that I have found through my research to better improve my own health. I am also sure that there are many other girls in similar boats as me that could use the suggested solutions to try and improve their own iron.

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