Micronutrients

for Female Athletes

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Introduction

Vitamins, minerals, and trace minerals are known as micronutrients. They are essential for many bodily processes which are important for health and performance. Micronutrients aid growth and development and are also essential for certain metabolic reactions. Although some vitamins and minerals are involved in energy pathways, they are not direct providers of energy. Most micronutrients must be obtained through the diet, because the body cannot produce them in large amounts, except for vitamin D which can be obtained from sunlight and dietary sources.

Athletes have higher energy intake demands in comparison to the general population, likely increasing their dietary micronutrient intake. However, in comparison to males, female athletes may be at an increased risk of micronutrient deficiencies due to potentially having a lower absolute energy intake, which could result in lower micronutrient intake. Female athletes also have an increased risk of low energy availability which can negatively affect micronutrient regulation and absorption.

In general, if an athlete is consuming a well-balanced and varied diet, which meets the demands of their training load, it is likely that they are consuming enough vitamins and minerals through dietary sources. Exceptions may be if athletes are following a restricted or low-calorie diet, or a vegan/vegetarian diet. In some circumstances, dietary supplementation of vitamins and/or minerals may be required. However, athletes should always base their nutrition around a 'food first' approach, with micronutrient supplementation used only when deemed necessary by a sports dietitian (or other qualified professional) to support health and/or performance. The following information will focus on four key micronutrients: iron, calcium, vitamin D, and folate. An overview of the roles of common vitamins and minerals is provided in Figure 1.

Vitamin A Helps with vision and fighting infection Dietary sources: Seafood, orange and green vegetables (i.e., carrot and spinach)	**Vitamin C** Important for bones, skin, muscle growth and immune function Dietary sources: Oranges, orange juice, peppers, kiwis, strawberries	**Vitamin D** Maintains bone strength and is important for the nervous system Dietary sources: Fish (i.e., salmon and mackerel), egg yolk Also obtained through sunlight
Vitamin E An antioxidant important in protecting against cell damage Dietary sources: Sunflower seeds, nuts, vegetable oil, broccoli	**Calcium** For healthy bones and teeth, and muscle contraction Dietary sources: Milk, yogurt, tofu, cheese	**Phosphorus** Important for maintaining bone and teeth health Dietary sources: Meat, fish, dairy products
Magnesium Helps to form protein and is important for immune function Dietary sources: Nuts, seeds, green vegetables	**Sodium** Essential for fluid balance, muscle contraction and the nervous system Dietary sources: Table salt	**Chloride** Helps with fluid balance Dietary sources: Table salt
Potassium Maintains fluid balance, muscle contraction and the nervous system Dietary sources: Meat, milk, fresh fruit	**Zinc** Important for optimal immune function Dietary sources: Lean meat, shellfish, legumes, nuts and seeds	**Iron** Helps to store and utilise oxygen Dietary sources: Red meat, nuts, beans

Figure 1: The main functions of micronutrients and common dietary sources

Iron

Iron is a mineral that is involved in various bodily functions, including the transport and delivery of oxygen in the blood. Iron plays an important role in other processes in the body, including:

- Energy production
- Cognitive function
- Immune function
- Growth and development

Guidance

Table 1 shows the Recommended Dietary Allowance (RDA) for iron, for non-vegetarians. The RDAs for vegetarians/vegans are 1.8 times higher due to the lower bioavailability of iron from plant-based foods. It should be noted that these guidelines are for the general population, as currently no athlete-specific guidelines exist. However, it is estimated that athletes may require an additional 1-2 mg of iron per day to replenish exercise-related iron losses. See Figure 2 for dietary sources of iron, and how much iron each source contains.

Table 1: Recommended Dietary Allowances (RDAs) for iron, for females of different life stages (NIH, 2023)

Life stage	RDA for iron (mg)
Children 9-13 years	8
Teenage girls 14-18 years	15
Adult women 19-50 years	18
Pregnant teenagers	27
Pregnant women	27
Breastfeeding teenagers	10
Breastfeeding women	9

mg = milligram

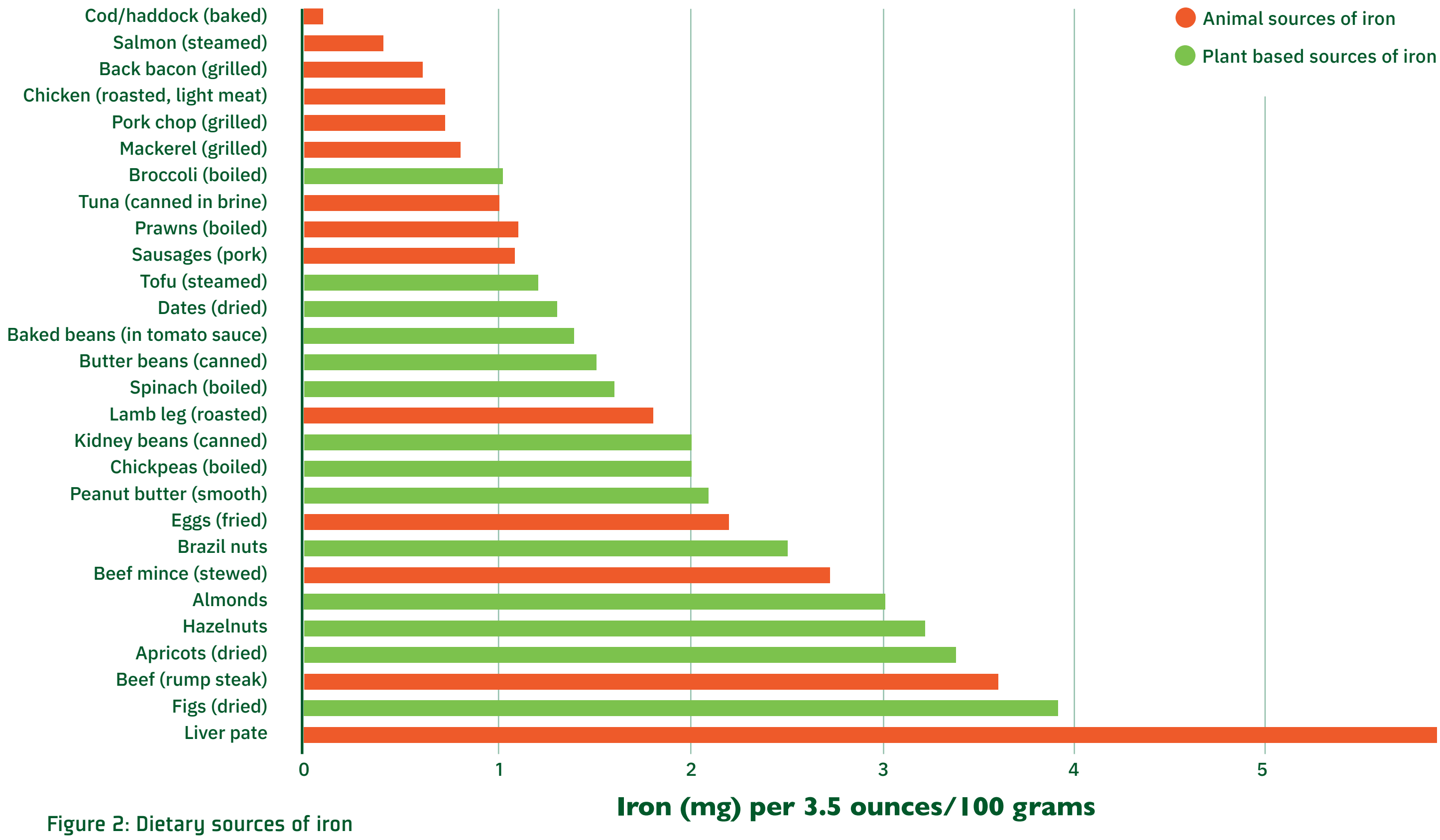


Figure 2: Dietary sources of iron

Iron deficiencies in athletes

If an athlete has an iron deficiency, this can lead to detrimental impacts to health and/or performance. Around 35% of female athletes have an iron deficiency, versus around 5% of the general population. In addition, female athletes are at a greater risk of being iron deficient in comparison to male athletes, with research showing that an iron deficiency is ~3 times more common in female athletes. There are several factors which can increase the likelihood of an iron deficiency (Figure 3).

Insufficient energy intake	A lower energy intake can increase the likelihood of dietary iron intake being insufficient.
Menstruation	Regular or heavy menstrual bleeding increases blood losses. Females may also have a lower overall ability to absorb iron in comparison to males, due to the fluctuation in estrogen throughout the menstrual cycle.
Plant-based diets	Iron from plant-based foods (i.e., non-heme iron) is not absorbed as well by the body in comparison to iron from animal-based foods (i.e., heme iron).
Exercise-induced iron loss	The mechanisms which contribute to this are sweating, gastrointestinal bleeding, haematuria (blood in urine), and footstrike hemolysis.

Figure 3: Factors which can increase the likelihood of an iron deficiency

Optimizing dietary iron intake

To prevent an iron deficiency, athletes should use a 'food first' approach to ensure that they are consuming sufficient amounts of iron in their diet. A sports dietitian can carry out a dietary assessment to advise on this. Iron absoprtion can be improved by combining iron intake (via iron-rich foods, or supplements) with other foods (Figure 4). Foods containing vitamin C can enhance the absorption of iron. Conversely, caffeine and calcium containing foods (or beverages) can inhibit iron absorption, and should not be consumed in close proximity to iron-rich foods/supplements (if the athlete's aim is to optimize iron absorption).

Dietary sources of iron, or iron supplements, can be consumed strategically around exercise. To maximize absorption, iron-rich foods/supplements should be consumed within 30 minutes prior to exercise, or 30 minutes after the completion of exercise. In addition, it has been shown that iron absorption is greater in the morning in comparison to the afternoon.

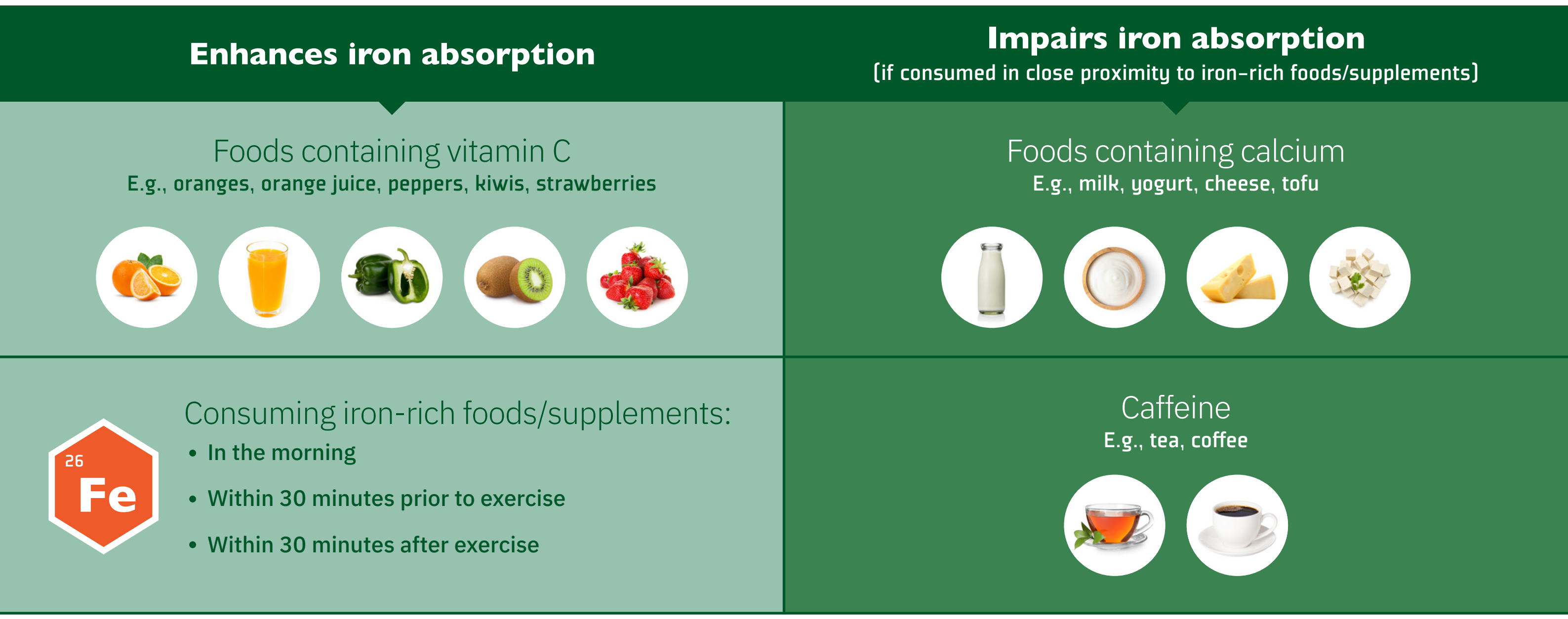


Figure 4: Factors which enhance and impair iron absorption

Identification of an iron deficiency

Athletes should be aware of the signs and symptoms of an iron deficiency (Figure 5). If an athlete is experiencing some of these signs and symptoms, they should book an appointment with a Medical Doctor to have their iron status assessed. Various hematological variables can be used to assess an athlete's iron status and classify the stage of an iron deficiency. However, it is suggested that the following three biomarkers should be included as a minimum for the clinical assessment of iron deficiency: serum ferritin (sFer), hemoglobin concentration (Hb), and transferrin saturation (TSAT). To improve the accuracy of assessing an athlete's iron status, blood collection should occur: (1) in the morning, after a day of rest before trianing resumes, (2) with the athlete in a health and hydrated state after an overnight fast.

Categorization of an iron deficiency

Once assessed, iron deficiencies can be split into three stages:

Stage 1 Iron depletion (ID)

Stage 2 Iron deficiency non-anemia (IDNA)

Stage 3 Iron deficient anemia (IDA)

Current research suggests that athlete performance is only impaired when the athlete reaches stage 3 (IDA), when oxygen transport is substantially diminished. However, the combined negative effects of stage 2 (IDNA), such as impaired function of oxidation enzymes, respiratory proteins, immune function, and perceptions of fatigue, may also decrease performance.

- **Heart palpitations**
- **Tiredness, lethargy, fatigue**
- **Poor recovery**
- **Reduction in performance**
- **Paleness**
- **Shortness of breath**
- **Lack of energy**

Figure 5: Signs and symptoms of an iron deficiency

Table 2: Female-specific cut-off values for the three stages of an iron deficiency

		Serum ferritin (sFer)	Hemoglobin concentration (Hb)	Transferrin saturation (TSAT)
Stage 1 ID	Iron reserves are depleted	<35 μg/L	>120 g/L	>16%
Stage 2 IDNA	Red blood cell production and iron supply is diminished	<20 μg/L	>120 g/L	<16%
Stage 3 IDA	Hb levels drop and anemia manifests	<12 μg/L	<120 g/L	<16%

Screening for iron deficiency

The screening frequency for iron deficiency differs between individuals, depending on an individual's iron deficiency history. The table below highlights the factors that should be considered when deciding how frequently an athlete should be screened for an iron deficiency. Please note that it is recommended that female athletes should be screened every 6 months, and therefore the information in regards to annual screening is not applicable to female athletes.

Table 3: Screening schedule for iron deficiency

Frequency	Factors to consider
Annually	• No history of iron deficiency • No history of irregular/excessive menses (or amenorrhea) • No reports of fatigue after extended rest • Strength/power-based sports with minimal endurance component • No iron related dietary restrictions (e.g., non-vegetarian, non-vegan) • No evidence of low energy availability • No intention to undertake hypoxic (altitude) training in the next 12 months • No underlying pathology (e.g., coeliac or Crohn's disease)
Every 6 months	• **Female** • History of iron deficiency (Stage 1) in the last 2 years • History (>24 months) of irregular/excessive menses • Intend to undertake high training loads in endurance or team sports • No reports of prolonged fatigue after extended rest • No iron related dietary restrictions (e.g., non-vegetarian, non-vegan) • No evidence of low energy availability • Intention to undertake hypoxic (altitude) training in the next 12 months
Every 3 months	• Recent history of iron deficiency (Stage 1, 2 or 3) in the last 2 years • Evidence of irregular/excessive menses or amenorrhea • High training loads in endurance or team sports • Prolonged fatigue even after extended rest • Reduced work capacity during training; unexplained poor performance • Restricted diet (e.g., vegetarian, vegan) • Evidence of low energy intake and availability • Intention to undertake hypoxic (altitude) training in the next 6 months

(Peeling et al., 2023)

Treatment of iron depletion/deficiency

1 Increasing dietary iron intake

This should be the first approach taken to improve iron stores. Dietary assessments can be used to explore an athlete's overall energy intake, consumption of key micronutrients, and the timing of nutrient consumption. Assessing these factors may highlight areas of concern in relation to iron intake and absorption. For example, athletes with high training volumes or who participate in weight-sensitive sports tend to be at higher risk of low energy availability, which can result in reduced dietary iron intake. Additionally, heme iron (found in animal-based foods) has greater efficiency of absorption compared to non-heme iron (found in plant-based foods), causing subsequent reduced iron absorption in vegetarian/vegan athletes.

2 Oral iron supplements

After dietary analyses, oral iron supplementation can be considered to support increases in dietary iron consumption. There are many forms of oral iron supplements ranging in dose, formulation, and chemical state, however ferrous sulfate tablets are the most common. Typically, oral iron supplements are consumed daily, with lower dosages used for athletes with low gastrointestinal tolerance, and higher dosages used for those with stage 3 IDA. A daily dose of ~100 mg in combination with a vitamin C source should increase sFer levels by 30–80% over a 6–8 week period.

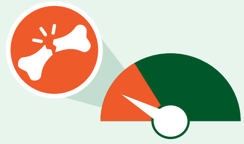
3 Intravenous (IV) iron infusions

The process of oral iron supplementation is relatively slow and, if the athlete has extremely low sFer stores, may have a relatively small impact. Therefore, in severe cases of IDA and when the athlete is unresponsive to oral iron supplementation, IV iron infusions may be considered. This is a rapid and effective method which bypasses the gut and delivers iron directly to the blood circulation. Research suggests IV iron treatment is only effective in increasing Hb in individuals with severe and persistent IDA. Note that there are complexities surrounding the World Anti-Doping Agency (WADA) rules that must be considered.

Calcium

Calcium is involved in many important processes in the body, for example muscle contraction and nerve function. Of relevance to female athletes, calcium is very important for bone health. During prolonged intense exercise, small amounts of calcium are lost through sweat. If this is combined with insufficient calcium intake through an athlete's diet, circulating calcium levels can be lowered. This can cause the breakdown of bone in the body, which is harmful to bone health and may ultimately contribute to stress fractures and osteoporosis. Therefore, it is important for athletes to include calcium-rich foods in their diet on a daily basis. It should be noted that there is emerging evidence that pre-exercise calcium intake can potentially offset loss of calcium in sweat, which may have a positive impact on bone health.

As estrogen promotes calcium absorption and retention in the bone, female athletes with low levels of estrogen (e.g., amenorrheic and post-menopausal athletes) may require additional calcium intake to maintain bone health. Research has found that amenorrheic athletes are up to 4x more likely to sustain a stress fracture compared to regularly menstruating athletes.



Guidance

Table 4 shows the RDAs for calcium. It should be noted that these guidelines are for the general population, as currently no athlete-specific recommendations exist. Athletes should not consume more than ~500-600 mg of calcium at one time in order to maximize absorption.

Table 4: Recommended Dietary Allowances (RDAs) for calcium, for females of different life stages (NIH, 2024)

Life stage	RDA for calcium (mg)
Children 9-13 years	1300
Teenage girls 14-18 years	1300
Adult women 19-50 years	1000
Pregnant teenagers	1300
Pregnant women	1000
Breastfeeding teenagers	1300
Breastfeeding women	1000

mg = milligram

Dietary intake

If an athlete does not currently meet the RDA, then they should be encouraged to incorporate more calcium-rich foods in their diet. Some easy ways to increase dietary calcium include drinking a glass of milk alongside breakfast, having some yogurt after meals, or including extra portions of tofu or green leafy vegetables in the diet (see Figure 6). Athletes should ensure that they have sufficient vitamin D levels (through dietary sources and sunlight exposure) because vitamin D aids the absorption of calcium from foods. Athletes should only supplement their diet with calcium after a review of their current dietary intake by a sports dietitian.

Whole or skimmed cow's milk
Serving size: 10.5 fl oz / 300 ml
Calcium: ~360 mg

Calcium enriched soy milk
Serving size: 10.5 fl oz / 300 ml
Calcium: ~360 mg

Kale (boiled)
Serving size: 3.5 oz / 100 g
Calcium: ~150 mg

Orange
Serving size: 1 medium size
Calcium: ~40 mg

Hard cheese
Serving size: 1 oz / 30 g
Calcium: ~220 mg

Tofu
Serving size: 3.5 oz / 100 g
Calcium: ~350-400 mg

Rice pudding
Serving size: 7 oz / 200 g
Calcium: ~200 mg

Dried figs
Serving size: 2.1 oz / 60 g
Calcium: ~150 mg

Greek yogurt
Serving size: 5.3 oz / 150 g
Calcium: ~150 mg

White bread
Serving size: 2 slices
Calcium: ~100 mg

Wholegrain bread
Serving size: 2 slices
Calcium: ~100 mg

Sardines in oil (canned)
Serving size: 2.1 oz / 60 g
Calcium: ~240 mg

Figure 6: Calcium content of foods

Vitamin D

Vitamin D is important for maintaining many aspects of health which are important for an athlete's performance, including:

- **Bone health**
- **Muscle function**
- **Cardiac structure and function**
- **Immune health**
- **Estrogen production**

Vitamin D deficiency

Vitamin D deficiencies are common in both athletes and the general population, and supplemental intake of vitamin D may be warranted after consulting with a qualified professional. The main way that vitamin D is obtained is through sunlight exposure (~80-90%), with only ~10-20% obtained through the diet. It should be noted that multiple factors can impact the ability of the body to synthesize vitamin D (Figure 7).

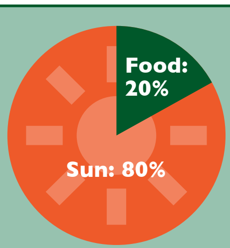
It is estimated that 33-42% of female athletes present with vitamin D insufficiency. Specific to females, vitamin D plays a key role in estrogen production. Therefore, the effects of vitamin D deficiency may also influence menstrual status and fertility, as well as bone health.

UV intensity	Latitudes 37° north or south of the equator will not be strong enough to stimulate the synthesis of vitamin D during the cooler months.
Clothing	Covering a large portion of the skin with clothing limits exposure to UV rays.
Skin color	Individuals with darker skin tones need longer exposure to UV from the sun to synthesize similar amounts of vitamin D.
Environment	Athletes who train indoors for long periods of time, or live in hot countries and avoid going outside in summer months, may have limited vitamin D exposure.

Figure 7: Factors which reduce vitamin D synthesis

Guidance

The guidance for obtaining sufficient vitamin D during summer and winter can be seen below in Figure 8.



Summer recommendations

Sunlight exposure

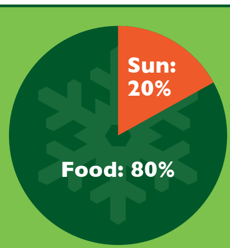
Time: 10am–3pm

Duration: ~15 min

Frequency: 6 days per week

Attire: t-shirt and shorts

Do not burn, apply sunscreen after ~15 min exposure



Winter recommendations

Supplementation

Supplement 1000–2000 IU of vitamin D3 daily, as regular daily doses appear to be more effective than monthly megadoses

Difficult to obtain this amount of vitamin D3 through foods

Toxicity is rare, but may occur when ingested doses exceed >10,000 IU/day

Figure 8: Guidance for obtaining sufficient vitamin D

Folate

Folate is a B vitamin which plays an important role in the production of new red blood cells. A folate deficiency may result in iron deficiency anemia, and performance may decline as a consequence. In females, a folate deficiency is especially common during pregnancy, due to the high folate demands associated with fetal growth and development. If a female athlete continues to train throughout their pregnancy, the high exercise demands may augment the likelihood of a folate deficiency. Oral contraceptive use is also associated with reduced plasma folate and red blood cell folate concentrations, therefore athletes using oral contraception may require an increase in folate consumption. Individual screening for folate status is recommended, especially throughout pregnancy.

Guidance

RDAs for folate can be seen in Table 5. It should be noted that these values have been produced for the general population, as folate requirements for athletes have not yet been established. The RDAs are listed as mcg of dietary folate equivalents (DFEs), which reflect the higher bioavailability of folic acid (~85%) compared to that of folate from foods (~50%). As such, it should be noted that:

- **1 mcg DFE = 1 mcg folate from food**
- **1 mcg DFE = 0.6 mcg folic acid from fortified foods or dietary supplements, consumed alongside foods**

Table 5: Recommended Dietary Allowances (RDAs) for folate for females of different life stages (NIH, 2022)

Life stage	RDA for folate (mcg DFE)
Children 9-13 years	300
Teenage girls 14-18 years	400
Adult women 19-50 years	400
Pregnant teenagers	600
Pregnant women	600
Breastfeeding teenagers	500
Breastfeeding women	500

DFE = Dietary Folate Equivalent, mcg = microgram

Dietary sources:

In many countries, common ingredients such as wheat flour and breakfast cereals are fortified with synthetic folate (folic acid). Foods naturally high in folate can be seen below:


Legumes (e.g., chickpeas)


Dark leafy greens (e.g., broccoli, bok choy, kale)


Oranges


Eggs

MICRONUTRIENTS

Vitamins, minerals, and trace minerals are essential for many bodily processes to help maintain health and performance.

Female athletes are at increased risk of obtaining micronutrient deficiencies.

Key micronutrients for female athletes

Micronutrient	Description	Guidance	Examples
26 Fe **Iron**	**Iron has several important roles within the body, including the transport and delivery of oxygen, energy production, cognitive function, immune function, and growth and development.**	• For adult women, the RDA for iron is >18 mg per day. This is increased to 27 mg of iron per day for pregnant women and teenagers. • To maximize iron absorption, iron should be consumed alongside foods containing vitamin C, and away from calcium containing foods and caffeine.	Red meat Hazelnuts Leafy vegetables Fish
20 Ca **Calcium**	**Calcium is important for bone health and the prevention of stress fractures, especially for exercising females with reduced circulating calcium levels.**	• For adult women, the RDA for calcium is 1000 mg per day, ideally consuming no more than ~500-600 mg at one time to maximize absorption. • Vitamin D enhances calcium absorption, so athletes should ensure optimal vitamin D intake/ exposure.	Cow's milk Tofu Cheese Plain yogurt
Vitamin D	**Vitamin D is important for maintaining many aspects of health and performance, including bone health, muscle function, cardiac structure and function, immune health, and estrogen production.**	• It is recommended that athletes consume a vitamin D supplement containing 1000-2000 IU per day during the winter months (October to March). • During the summer months, a sensible amount of sunlight exposure, approximately 15 minutes per day to arms and legs, is sufficient to maintain vitamin D status.	Sun exposure Milk Egg yolk Oily fish
B_9 **Folate**	**Folate is a B vitamin which helps with the production of new red blood cells. Deficiencies are especially common in pregnant women, so individual screening is recommended.**	• For adult women, the RDA for folate is 400 mcg. This is increased to 600 mcg for pregnant women. • However, these recommendations are aimed at the general population, as folate requirements for athletes have not yet been established.	Legumes Oranges Dark leafy vegetables Eggs

RDA = Recommended Dietary Allowance

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