GATORADE SPORTS SCIENCE INSTITUTE

The Female Athlete

Sports Nutrition and Hydration Resources for Practitioners

Introduction

The Gatorade Sports Science Institute (GSSI) was founded in 1985, and has the mission of helping athletes optimize their health and performance through research, innovation, education and service in hydration and nutrition science. GSSI has a long history of sports science research, education, and providing service to athletes, including female athletes.

Participation in female sport is continually rising at all levels. It is critical that all sports health professionals have access to evidence-based educational information specifically related to female athlete health and performance. As such, GSSI have created this toolkit specifically for sports professionals such as sports dietitians, athletic trainers, and strength and conditioning coaches who work with female athletes.

The aim of this toolkit is to provide evidence-based recommendations to support the well-being and performance of female athletes. This toolkit is not designed to cover all topics within sports nutrition, nor should the toolkit be considered as a consensus for practice in sports nutrition. Instead, the toolkit aims to provide introductory materials to support best practice. The toolkit begins by covering the fundamentals of sports nutrition, such as dietary carbohydrate, protein and fat needs, as well as hydration. Following this, fueling requirements around exercise are covered. Finally, topics that are of particular importance to female athletes are covered, such as energy availability, bone health, and the menstrual cycle.

www.gssiweb.org/en/cohorts/female-athlete

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Contents

Dietary Carbohydrate

Introduction

All of the foods and fluids that athletes eat provide nutrients which have specific roles in the body. Carbohydrates are a macronutrient (along with protein and fat), which are required in larger quantities in comparison to micronutrients (vitamins and minerals). The information below will provide guidelines on daily carbohydrate recommendations to support both the health and performance of female athletes. In addition, it will cover some of the barriers that female athletes may face in order to meet carbohydrate recommendations.

Dietary carbohydrate

There are three main types of dietary carbohydrate which are:

Sugar

also known as monosaccharides or disaccharides because they are made up of single or double sugar molecule(s). They can be naturally occurring sugars (e.g., in fruit or milk), or added sugars which are those added during processing (e.g., fruit canned in syrup or sugar added to make a cookie). On food labels, sugar is often referred to by its chemical name (e.g., glucose, sucrose, fructose, lactose, maltose). Sugars are an energy source for the body.

Starch

also known as polysaccharides because they are more complex carbohydrates made up of multiple sugar molecules joined together by glycosidic bonds. When starches are consumed, they are broken down by the body into units of glucose, which provides energy to the body.

Fiber

a complex group of sugars (polysaccharides) from plant foods which cannot be digested in the small intestine. Instead, they are completely or partially broken down (i.e., fermented) by bacteria in the large intestine.

Monosaccharide
Single sugar

Disaccharide
Two sugar molecules linked

Polysaccharide
Many sugar molecules linked

Carbohydrate use and storage

Ingested dietary carbohydrates provide energy to the muscles, brain, and nervous system. Following ingestion, carbohydrates are broken down into smaller sugar molecules, which are converted into glucose by the liver to be used for energy. If glucose in the bloodstream exceeds energy needs, glucose will be converted into glycogen and stored in the body. The body can store ~500 grams of carbohydrate as glycogen in the liver and muscle, which can be broken down and used when energy is needed.

The liver can store up to ~100 grams of glycogen at any given time. This glycogen is primarily used to maintain blood sugar and energy levels throughout the day. In the muscles, a larger amount of glycogen can be stored (~400 grams). The glycogen in the muscles is a secondary storage facility, carbohydrates are stored there when the liver has reached capacity. For athletes, muscle glycogen, and the breakdown of glycogen to glucose in the liver, is used by the muscles during exercise to provide energy.

Each gram of carbohydrate provides ~4 kcal of energy.

The contribution of carbohydrate to energy metabolism during exercise changes depending on exercise type (Figure 1). During high intensity endurance or sprint-type exercise, carbohydrates are the predominant energy source. During this type of exercise, the body will use glycogen stores, and sometimes they may even become depleted. When glycogen stores run low, the body may fatigue which can result in impaired physical and cognitive performance.

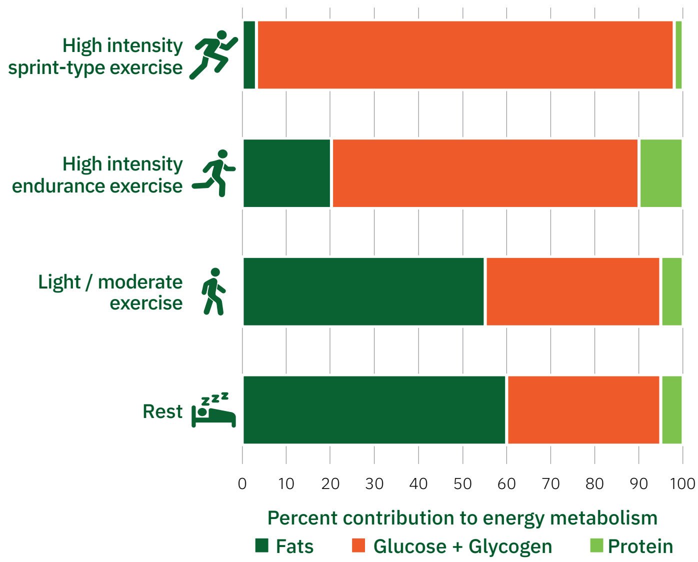

Figure 1: Substrate metabolism at rest and during different exercise types and intensities

Daily carbohydrate recommendations

Due to carbohydrate utilization varying during different exercise occasions, daily carbohydrate intake recommendations are dependent upon the intensity and duration of exercise being performed (Figure 2). The aim is to ensure that sufficient carbohydrate is consumed to provide energy to working muscles, the central nervous system, and other bodily processes. Figure 3 shows the carbohydrate content of different foods which can contribute to overall daily carbohydrate intake.

3-5 g/kg BM/day 180 – 300 g* — **Light activity**

5-7 g/kg BM/day 300 – 420 g* — **Moderate activity** (e.g., 1 hour per day)

6-10 g/kg BM/day 360 – 600 g* — **Endurance** (e.g., 1-3 hours per day)

8-12 g/kg BM/day 480 – 720 g* — **Extreme activity** (e.g., >4 hours)

*Recommendations in grams (g) calculated for a 60 kg/132 lb female
g/kg BM/day = grams per kg of body mass per day

Figure 2: Daily carbohydrate intake based on activity level

Figure 3: Carbohydrate and fiber content of foods and drinks

Table 1
Daily carbohydrate intake recommendations based on exercise intensity and body mass

Light activity: 3–5 g/kg BM/d; Moderate activity: 5–7 g/kg BM/d; Endurance: 6–10 g/kg BM/d; Extreme activity: 8–12 g/kg BM/d

Body mass		Recommended carbohydrate intake (g) per day									
kg	lb	3 g/kg BM/d	4 g/kg BM/d	5 g/kg BM/d	6 g/kg BM/d	7 g/kg BM/d	8 g/kg BM/d	9 g/kg BM/d	10 g/kg BM/d	11 g/kg BM/d	12 g/kg BM/d
45	99	135	180	225	270	315	360	405	450	495	540
50	110	150	200	250	300	350	400	450	500	550	600
55	121	165	220	275	330	385	440	495	550	605	660
60	132	180	240	300	360	420	480	540	600	660	720
65	143	195	260	325	390	455	520	585	650	715	780
70	154	210	280	350	420	490	560	630	700	770	840
75	165	225	300	375	450	525	600	675	750	825	900
80	176	240	320	400	480	560	640	720	800	880	960
85	187	255	340	425	510	595	680	765	850	935	1020
90	198	270	360	450	540	630	720	810	900	990	1080
95	209	285	380	475	570	665	760	855	950	1045	1140
100	221	300	400	500	600	700	800	900	1000	1100	1200
105	232	315	420	525	630	735	840	945	1050	1155	1260
110	243	330	440	550	660	770	880	990	1100	1210	1320

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g/kg BM/day	Breakfast	Lunch	Dinner
3-5	Oatmeal with berries	Chicken salad and a banana	Fish with roasted vegetables
5-7	+ a banana	+ bread rolls	+ a rice based salad
6-10	+ yogurt and granola	+ a side of potatoes	+ a large glass of orange juice
8-12	+ two slices of toast	+ a milk based fruit smoothie	+ a large fruit salad

Figure 4: Examples of how the carbohydrate content of meals can be altered to meet daily carbohydrate recommendations

Dietary fiber

It is recommended for athletes to consume 25-35 grams of fiber per day. Dietary fiber provides many benefits to the body including:

- Improves gastrointestinal function and bowel movements
- Supports a healthy gut microbiome
- Helps to promote satiety
- Associated with lower risk of heart disease, type 2 diabetes, and colon cancer

While dietary fiber intake provides many health benefits, there is a reason for practitioners to be cautious if athletes regularly have a very high fiber intake (i.e., above the RDA, >35g fiber). Research in female endurance athletes found high levels of dietary fiber intake to be associated with low energy availability and functional hypothalamic amenorrhea (i.e., loss of menstrual cycle). These associations might be due to:

1. High fiber intake increasing fecal fat excretion, which in turn can reduce energy absorption
2. Dietary fiber increasing satiety, which when coupled with high-intensity exercise may suppress appetite, decrease hunger, and reduce the total amount of energy consumed during a meal
3. Excessive fiber increasing the likelihood of gastrointestinal discomfort e.g., bloating and diarrhea, which in turn may impact subsequent energy intake

Therefore, while it is important for athletes to include fiber within their diet, practitioners should be aware of how much fiber female athletes are consuming. In addition, fiber intake should be limited before and during exercise to reduce the risk of gastrointestinal symptoms.

Do female athletes meet carbohydrate recommendations?

It has been shown that female athletes across a range of sports struggle to meet daily carbohydrate recommendations and do not adapt their carbohydrate intake based on their training load. This could be due to a number of reasons including:

- High consumption of low energy, nutrient dense carbohydrates (e.g., fresh fruits and vegetables)
- Body weight and/or composition fears
- Substituting sports drinks with low calorie sweetened drinks during high-intensity and/or prolonged exercise
- Lack of education regarding the importance of carbohydrates
- Negative perception of carbohydrates on social media

Meeting the upper end of the carbohydrate recommendations requires a large amount of food to be consumed, which may also be a contributing factor to female athletes not meeting the recommendations. For example, in food terms, 10 g/kg BM/day of carbohydrate for a 132 lb (60 kg) female (= 600g carbohydrate) is equivalent to either:


11 potatoes


1.8 kg white rice (uncooked)


1.7 kg pasta (uncooked)

*It is not recommended to eat the amounts shown above in one day, a balanced diet is necessary

Excerpts from a qualitative study regarding carbohydrate intake in professional female soccer players bring to life some of the barriers faced by female athletes:

"It was quite difficult for me to actually transition into eating, like, more carbs and more calories because I was scared of putting weight back on. Sometimes I just don't want to eat carbs because I know they will make me fat."

– Player

"I've had conversations with players where I'm like 'you need to have carbs at least on match day minus one, making sure you're fueling for the game ahead' and they're a bit reluctant to want to take on that amount of carbs. Like 'I don't like eating that many carbs, that's not something I do.'"

– Sports scientist

"The players don't want a mixed protein shake, they just want a protein shake because the mixed protein shake has got too much carbs in and it's like 'wow, they're not willing to have carbs after a game, that's pretty scary' I guess... The fact that they're worried about some carbohydrate powder in a protein shake because they think it will make them fat is quite a scary thing."

– Sports dietitian

McHaffie et al. (2022)

These excerpts highlight that providing education to female athletes regarding the role of carbohydrates in the diet is key. In addition, practitioners should work with female athletes on an individual basis to discuss any barriers that they face to meeting their daily carbohydrate needs, and to find ways to meet their individual carbohydrate recommendations.

Low carbohydrate diets

Some athletes may purposefully follow a low carbohydrate diet on a long-term basis, i.e., a 'ketogenic' or 'low carbohydrate, high fat' diet. This may be for a range of reasons including a lack of understanding of the importance of carbohydrates for performance, fad diets, social media influence, "carb-phobia", perceived positive body composition outcomes, etc. Very low carbohydrate intake for a prolonged period can lead to a range of outcomes including:

- **Premature fatigue during exercise**
- **Impaired performance at higher intensities**
- **Poor cognitive performance e.g., reduced alertness, difficulty concentrating**
- **Poor recovery between bouts of exercise**

Athletes should therefore be educated around the potential performance consequences of following a low carbohydrate diet. It is however worth noting that a low carbohydrate diet may be useful during very short-term periods (i.e., 3-7 days) where weight loss is required to meet a certain weight target e.g., Olympic weightlifting, wrestling, judo and boxing. This is because there is evidence that this is effective for reducing fat mass while maintaining power and strength during very short-term periods. If this strategy is used, it should be carefully planned and managed by a sports dietitian, and should not be used for long periods of time.

Carbohydrate periodization

If athletes need help adjusting their carbohydrate intake to meet the demands of exercise on a day-by-day basis, carbohydrate periodization provides a practical solution. This strategy can help to support both performance and recovery through strategic timing of carbohydrate intake. Figure 5 provides a visual representation of how carbohydrate intake can be altered depending on the intensity and duration of exercise being completed.

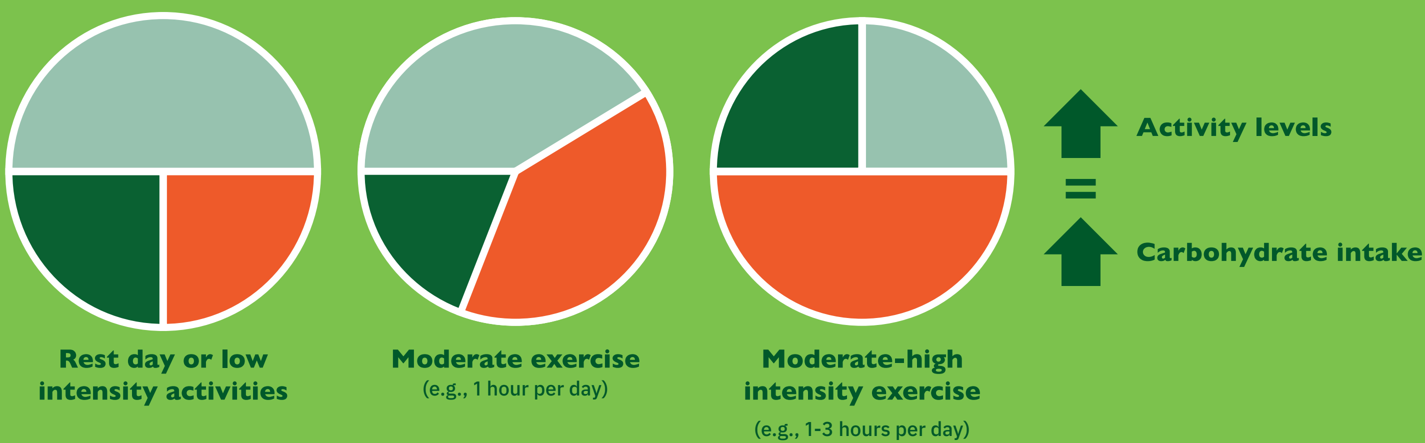


Figure 5: How to periodize carboydrate intake based on activity levels

Carbohydrate · Fruit and veg · Protein

Should athletes alter carbohydrate intake based on menstrual cycle phase?

Popular media would suggest that female athletes should alter their diet, including their carbohydrate intake, during different phases of the menstrual cycle. **However, there currently is not enough research to back this statement.** There is some research to suggest that glycogen storage may be reduced during the follicular phase of the menstrual cycle compared to the mid-luteal phase. Nevertheless, providing that daily carbohydrate intake is sufficient for the exercise demands, this should not have an impact on performance.

DIETARY CARBOHYDRATE

Sugar | Starch | Fiber

Carbohydrate containing foods


Sweet potatoes
1 cup ≈ 30 g carbohydrate


Standard potatoes
1 cup ≈ 26 g carbohydrate


Couscous
1 cup ≈ 56 g carbohydrate


Whole wheat pasta
1½ cups ≈ 50 g carbohydrate


Gatorade Thirst Quencher
20 oz (1 bottle) ≈ 30 g carbohydrate


Brown rice
1 cup ≈ 46 g carbohydrate


Banana
1 medium ≈ 30 g carbohydrate


Oats
½ cup ≈ 30 g carbohydrate


Wholegrain bread
2 slices ≈ 30 g carbohydrate

3-5 g/kg BM/day
180 – 300 g
Light activity

5-7 g/kg BM/day
300 – 420 g
Moderate activity
(e.g., 1 hour per day)

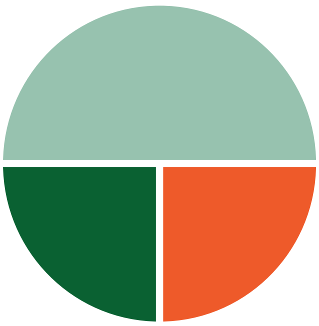
6-10 g/kg BM/day
360 – 600 g
Endurance
(e.g., 1-3 hours per day)

8-12 g/kg BM/day
480 – 720 g
Extreme activity
(>4 hr)

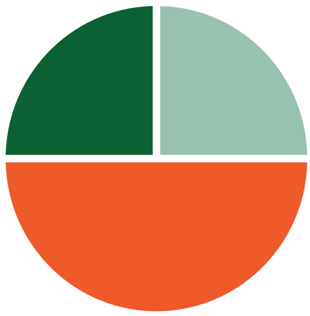
Examples based on a 60 kg/132 lb female

↑ **Activity levels** = ↑ **Carbohydrate intake**

Carbohydrate periodization


Rest day or low intensity activities


Moderate exercise
(e.g., 1 hour per day)


Moderate-high intensity exercise
(e.g., 1-3 hours per day)

● Carbohydrate ● Fruit and veg ● Protein

Carbohydrate intake and menstrual cycle phase

There is currently insufficient research to suggest that female athletes should alter their carbohydrate intake during different phases of the menstrual cycle. Female athletes should focus on ensuring that their carbohydrate intake is sufficient for their exercise demands, regardless of menstrual cycle phase.

Dietary Protein

Introduction

Dietary protein is an essential macronutrient which helps the growth of new tissue and the remodeling of skeletal muscle after exercise. Proteins have many different roles in the human body. For athletic performance, protein is commonly associated with muscle and movement. However protein has many other important roles including hormone production, providing structure for cells and tissues, supporting immune system function, moving essential molecules around the body, and enzyme production. Therefore, consuming sufficient protein in the diet is important for all athletes. The information below will discuss the role of protein in the body, how protein supports recovery, and practical advice on how to incorporate protein into an athlete's diet.

The process of building muscle

Human skeletal muscle is constantly being broken down and re-built into new structures, this process is known as protein turnover. When muscle protein synthesis (MPS) is greater than muscle protein breakdown (MPB), the net protein balance is positive, and muscular growth can occur (Figure 1). Amino acids (the units which make up proteins) provided through dietary sources can be used for MPS. Exercise increases both MPS and MPB, therefore muscle protein turnover is high. The exercise-associated adaptations that occur within muscles will depend on the type of exercise performed, as well as the dietary nutrients available.

The figure below shows MPS and MPB in response to three equally sized protein containing meals after either: **(A) no exercise or, (B) resistance exercise.** The shaded areas represent muscle protein accretion, and the non-shaded areas represent muscle protein loss. This demonstrates the importance of consuming protein following exercise to maximize MPS.

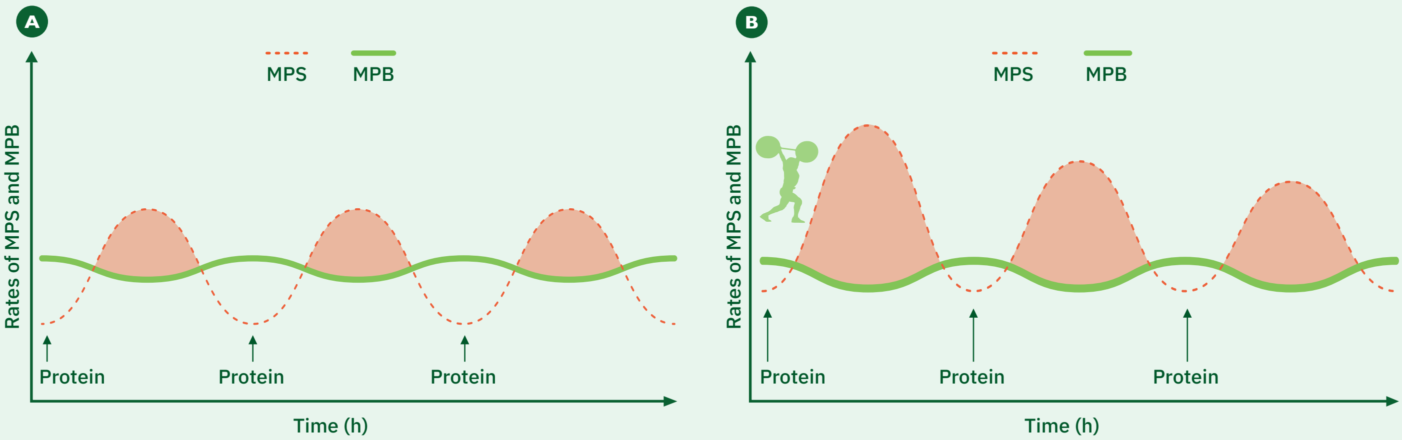


Figure 1: MPS and MPB responses following protein ingestion after either (A) no exercise and (B) resistance exercise

Net protein balance

It is important to ensure that athletes are in either a positive net protein balance, or muscle maintenance, to ensure that they are not losing muscle mass (Figure 2). Athletes can achieve this by regularly consuming adequate amounts of protein in meals and snacks, alongside completing resistance exercise.

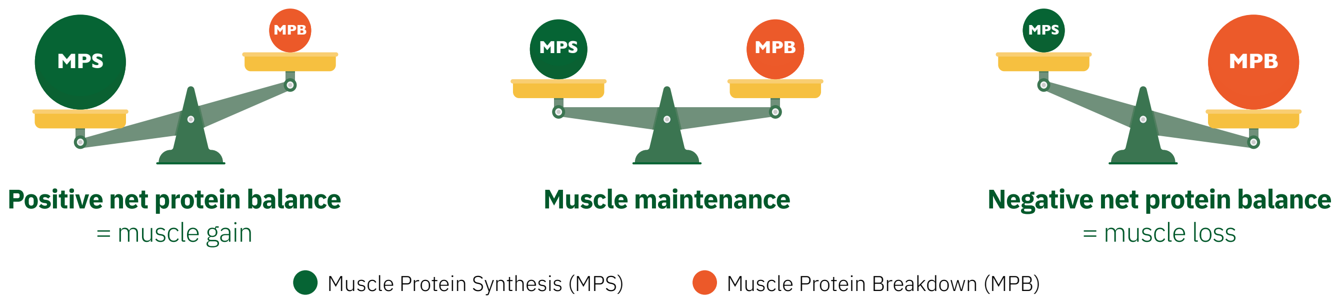
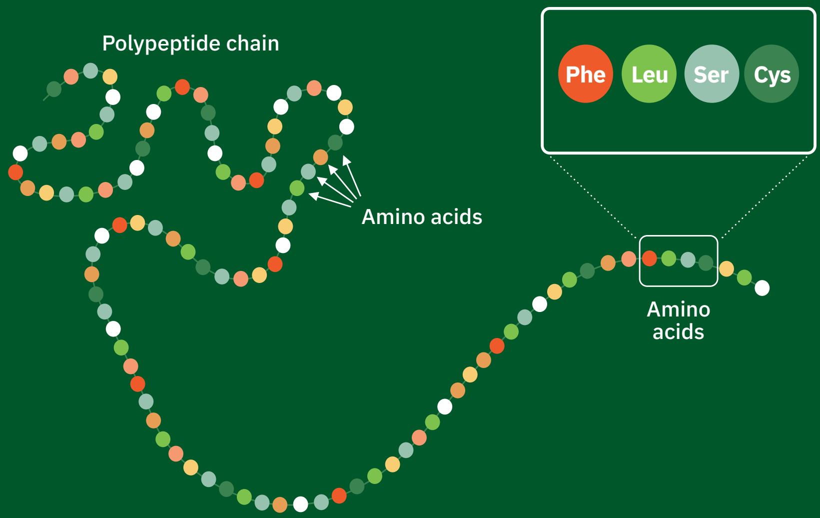


Figure 2: Net protein balance

Dietary protein

Proteins are composed of units called amino acids. There are 20 different types of amino acids, and it is the sequence of these amino acids (also known as a polypeptide chain) that determines the structure and function of a protein.

Amino acids are classified into two groups: essential and non-essential. The body can synthesize (produce) non-essential amino acids, but essential amino acids (EAAs) must be consumed through the diet. Foods which contain all EAAs are considered 'complete' dietary proteins. This is typically animal-based foods such as meat, poultry, fish, eggs, and dairy foods. Plant-based foods (fruits, vegetables, grains, nuts, and seeds) often lack one or more EAA. Combining different plant-based foods that are high in protein is a good strategy for achieving intake of all EAAs within a meal.



Examples of complete dietary proteins


Dairy


Poultry


Fish


Soy


Red meat

Essential amino acids	Non-essential amino acids
Not produced by the body	Produced by the body
Important to consume within diet	Not crucial to consume within diet
Histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, valine	Alanine, arginine, asparagine, aspartic acid, cysteine, glutamic acid, glutamine, glycine, proline, serine, tyrosine

Dietary protein source and quality

Protein sources contain different amino acid profiles. Both animal-based and plant-based protein sources can play important roles in a balanced diet by contributing a range of amino acids. Creating meals with a mixture of various protein sources, whether from animal- or plant-based sources, helps ensure nutritional needs are met.

Protein quality refers to the nutritional value and bioavailability of the protein. It assesses the ability of a protein to provide EAAs in proportions that meet the body's requirements for growth, maintenance, and repair. Protein quality is measured using a variety of indices, however the most accepted and understood index is the Protein Digestibility Corrected Amino Acid Score (PDCAAS) and the Digestible Indispensable Amino Acid Score (DIAAS). Food sources with high PDCAAS values include eggs, ground beef, whey, casein, milk, and soy.

Factors influencing protein quality

Amino acid profile
High-quality protein sources contain all essential amino acids.

Digestibility
Highly digestible proteins are more efficiently utilized by the body for various physiological functions.

Bioavailability
Refers to the extent to which the body can absorb and use the amino acids from a protein source. Bioavailability can be influenced by factors such as processing methods, food matrix, and antinutritional factors.

Figure 3: Factors influencing protein quality

Common dietary sources of protein

1 medium chicken breast
Serving size: 4.2 oz / 120 g
Protein: 38 g

1 small sirloin steak
Serving size: 3.9 oz / 110 g
Protein: 37 g

Small portion lean ground beef
Serving size: 3.5 oz / 100 g
Protein: 22 g

Half a can of tuna
Serving size: 3.2 oz / 90 g
Protein: 21 g

1 fillet of salmon
Serving size: 3.5 oz / 100 g
Protein: 23 g

1 medium fillet of cod
Serving size: 3.6 oz / 100 g
Protein: 24 g

1 plate prawns
Serving size: 4.2 oz / 120 g
Protein: 21 g

3 medium eggs
Serving size: 6.4 oz / 180 g
Protein: 21 g

1 container cottage cheese
Serving size: 8.8 oz / 250 g
Protein: 23 g

Greek yogurt
Serving size: 7.1 oz / 200 g
Protein: 20 g

1 large glass milk
Serving size: 20.1 fl oz / 568 ml
Protein: 19 g

Skimmed milk powder
Serving size: 2.1 oz / 60 g
Protein: 21 g

1 scoop of whey, soy or casein protein
Serving size: 1.1 oz / 30 g
Protein: 20–25 g

Tempeh
Serving size: 3.5 oz / 100 g
Protein: 21 g

Seitan
Serving size: 3.5 oz / 100 g
Protein: 24 g

Soy flakes
Serving size: 1.8 oz / 50 g
Protein: 27 g

Large plate quinoa
Serving size: 10.6 oz / 300 g
Protein: 21 g

Mixed nuts
Serving size: 3.2 oz / 90 g
Protein: 20 g

Tofu
Serving size: 3.5 oz / 100 g
Protein: 24 g

4 tablespoons peanut butter
Serving size: 2.1 oz / 60 g
Protein: 19 g

Mycoprotein
Serving size: 7.1 oz / 200 g
Protein: 22 g

1 plate lentils
Serving size: 8.8 oz / 250 g
Protein: 19 g

1 can chickpeas
Serving size: 8.1 oz / 230 g
Protein: 17 g

1 cup edamame beans
Serving size: 7.1 oz / 160 g
Protein: 18 g

1 can baked beans
Serving size: 14.7 oz / 415 g
Protein: 21 g

Daily protein intake recommendations

Female athletes require protein to support adaptation and muscular repair in response to exercise. It is recommended that athletes consume 1.2 – 2.0 grams of protein per kg of body mass per day (g/kg BM/d).

Athletes might require higher protein intakes to:

- Optimize muscle adaptation/recovery during periods of higher frequency/intensity training, or a new training stimulus
- Help maintain muscle mass if sudden or reduced inactivity occurs (e.g., following an injury)
- Prevent increased protein oxidation if carbohydrate intake is low, or if an athlete has low energy availability.

Table 1: Daily protein intake recommendations relative to body mass

Body mass		Recommended protein intake (g) per day based on body mass								
kg	lb	1.2 g/kg BM/d	1.3 g/kg BM/d	1.4 g/kg BM/d	1.5 g/kg BM/d	1.6 g/kg BM/d	1.7 g/kg BM/d	1.8 g/kg BM/d	1.9 g/kg BM/d	2.0 g/kg BM/d
60	132	72	78	84	90	96	102	108	114	120
65	143	78	85	91	98	104	111	117	124	130
70	154	84	91	98	105	112	119	126	133	140
75	165	90	98	105	113	120	128	135	143	150
80	176	96	104	112	120	128	136	144	152	160
85	187	102	111	119	128	136	145	153	162	170
90	198	108	117	126	135	144	153	162	171	180
95	209	114	124	133	143	152	162	171	181	190
100	221	120	130	140	150	160	170	180	190	200
105	232	126	137	147	158	168	179	189	200	210
110	243	132	143	154	165	176	187	198	209	220

g/kg BM/d = grams per kg of body mass per day

Timing of protein intake throughout the day

To maximize adaptations, athletes are advised to evenly distribute their consumption of protein within their meals and snacks throughout the day, in combination with appropriate quantities of other macro- and micronutrients. Consuming a meal or snack which includes ~20-40g protein every 3-4 hours is advisable.

Signifies when protein (~20-40 g) should be consumed

Plant-based proteins

Athletes may choose to follow a plant-based diet. The anabolic properties of plant-based proteins are generally lower, likely due to their reduced EAA content when compared to high-quality animal-derived proteins, with many plant-derived proteins being deficient in one or more amino acid(s). In addition, obtaining a sufficient amount of protein from plast-based foods often requires a higher energy intake in comparison to animal-based options (Figure 4). Despite this, with careful planning, athletes following a plant-based diet can consume adequate protein from plant-based foods.

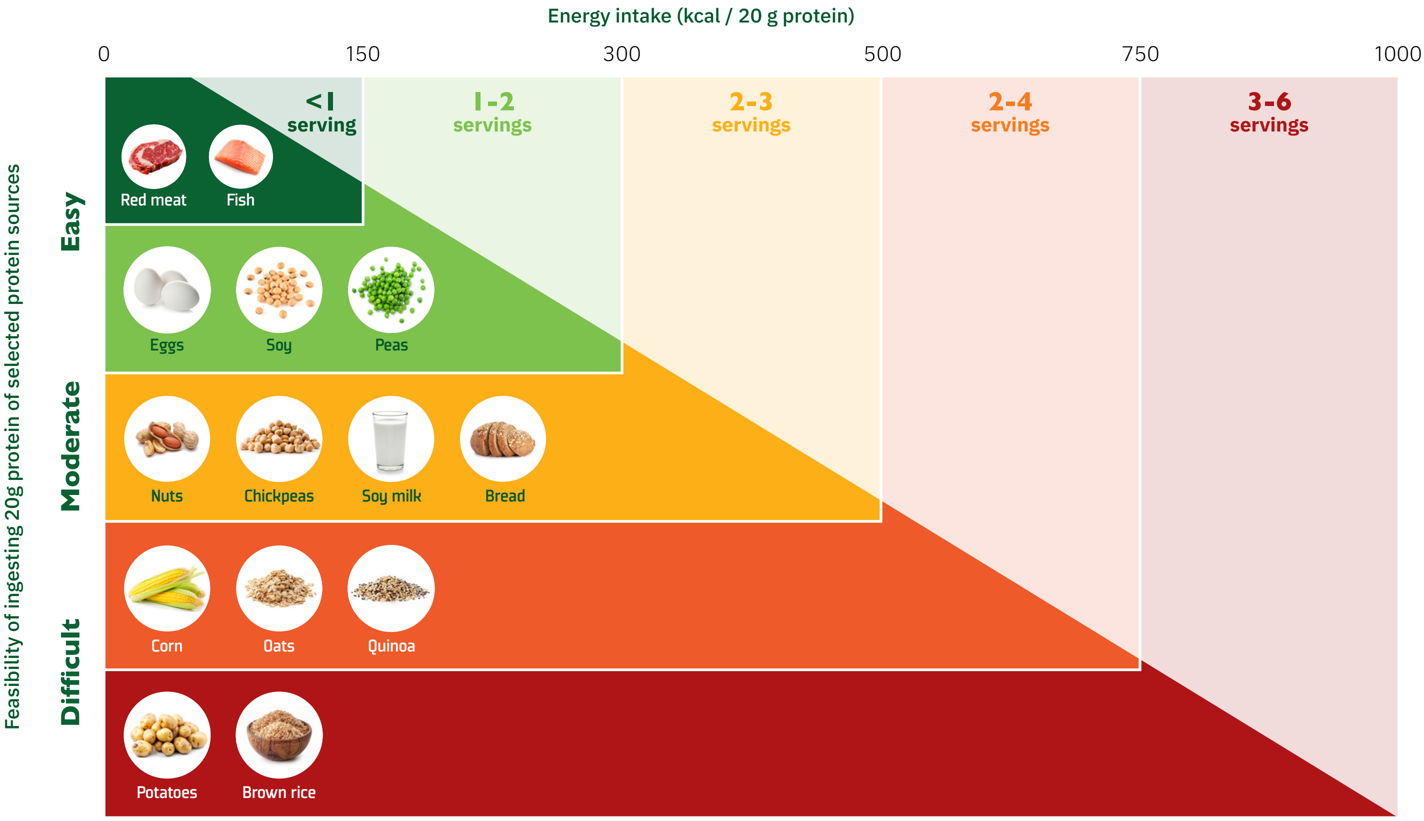


Figure 4: Feasibility to consume 20g protein by consuming whole foods (x-axis) expressed as the number of servings that would be required

Considerations

Those relying on plant-based proteins should ensure they are eating a variety of foods in order to meet their EAA needs, and to support recovery and training adaptations. Combining different plant-based protein sources throughout the day in meals and snacks is a good strategy to ensure that all EAAs are consumed. It should be noted that there are several plant-based foods which are considered complete proteins, and therefore are not lacking in any EAAs (Figure 5).

Plant-based protein, in its natural form, has lower natural digestibility compared to animal-based protein. Processing methods such as heating, soaking, or boiling can improve the digestibility of plant-based proteins. By combining different food groups, increasing portion sizes, and enhancing amino acid availability through processing or cooking, athletes following a plant-based diet can effectively stimulate MPS throughout the day.

Regarding the use of plant-based proteins for recovery and muscle gain, several studies have shown that consuming 30g of protein from plant-based sources (potato or a blend) leads to similar increases in MPS compared to milk protein. Therefore, plant-based proteins are a suitable option post-exercise.

Figure 5: Examples of plant-based foods which are complete proteins

Protein intake around exercise

Exercise causes a slight increase in the oxidation of protein, however protein is not an important energy source during exercise. The energy requirements for exercise are primarily met by carbohydrate and fat. Therefore, protein intake is not a priority immediately prior to, or during exercise. Post-exercise, while there does not appear to be a defined 'window of opportunity', it is important for athletes to incorporate high quality protein into their diet. Consuming protein source(s) which are rich in leucine and contain all EAAs is generally regarded as an effective means to 'turn on' and support maximal rates of MPS immediately after exercise. Ideally, meals/snacks should include ~20-40g of protein, or 0.25-0.30 g/kg BM of protein. When participating in intense whole-body exercise, the protein serving post-exercise should ideally be at the upper end of the recommendation (i.e., 30-40g).

Post-exercise, optimal choices include a balanced meal containing both lean protein and carbohydrates, or any of the snack choices below:

Eggs and toast | Yogurt and granola | Cottage cheese and fruit | Tuna and crackers | Hummus and pita | Protein shake and a banana

Figure 6: Post-exercise snack options

The importance of leucine

Leucine is an EAA which is important in activating the signaling pathway for MPS. Ingesting a sufficient quantity of leucine (2.5-5.0 g) has been shown to independently stimulate increases in MPS, making the leucine content of dietary protein an important factor to consider. However, it should be noted that leucine does not stimulate a rise in MPS if a full complement of EAA is absent. Therefore, ingesting complete dietary proteins remains important. Foods with a high leucine content include:

Chicken breast | Turkey | Pork | Tuna | Salmon | Pine nuts

Figure 7: Foods with a high leucine content

Protein powders

Protein powders provide a convenient way for athletes to consume additional protein within their diet. Ideally, the majority of an athlete's protein intake should be consumed via whole foods. However, protein powders may be useful when an athlete struggles to meet their daily protein needs through whole foods, or when access to high quality protein is limited e.g., when travelling.

Whey and casein protein (both milk proteins), as well as soy protein, are complete protein sources which have been shown to promote MPS. Soy protein provides a suitable option for athletes following a vegan diet, as well as protein blends which contain a range of plant-based proteins to achieve a full complement of EAA.

WHEY

Whey Protein Isolate
25-30 g serving size suggestion
~2.5 g leucine per serving

SOY

Soy Protein Isolate
25-30 g serving size suggestion
~2.0 g leucine per serving

CASEIN

Casein Protein
25-30 g serving size suggestion
~2.0 g leucine per serving

Sleep

Sleep is often an overlooked occasion for recovery. If protein is ingested prior to sleep, it is digested and absorbed, and used in muscle remodeling. Some pre-sleep protein options include:

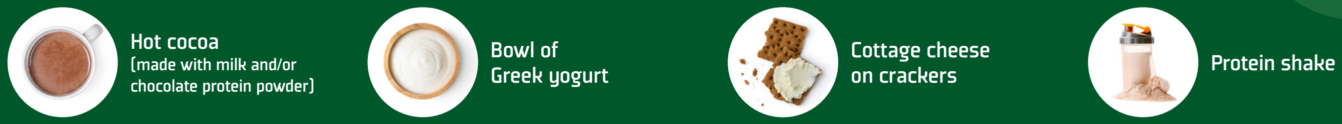


Figure 8: Pre-sleep snacks containing protein

Female specific requirements

Research investigating protein requirements specifically for female athletes is limited. However, determining optimal intake within total energy needs is crucial. Female athletes should aim for 0.25-0.30 grams of protein per kilogram of body mass (per serving) to meet their individual needs. Additionally, they should prioritize nutrient-dense protein sources and consider the timing of intake, especially after exercise.

Menstrual cycle

A small number of studies have suggested that there is a small increase in protein utilization at rest and during exercise during the luteal phase of the menstrual cycle.

Bone health

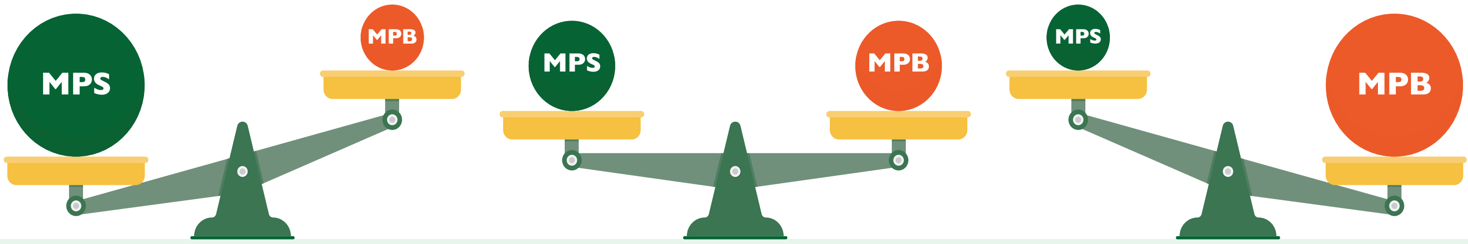
Protein plays an important role in optimizing bone health in female athletes (see 'Bone Health' for more information).

Menopause

Protein is a key dietary component during peri-menopause and post-menopause in order to help maintain skeletal muscle mass.

GATORADE SPORTS SCIENCE INSTITUTE™

DIETARY PROTEIN



Positive net protein balance
= muscle gain

Muscle maintenance

Negative net protein balance
= muscle loss

Muscle Protein Synthesis (MPS) Muscle Protein Breakdown (MPB)

Daily protein intake recommendations

1.2 g/kg BM/day – **2.0 g/kg BM/day**

Consuming a meal or snack which includes ~20-40g protein every 3-4 hours is advisable

Common dietary sources of protein


Sirloin steak


Canned tuna


Eggs


Mixed nuts


Tofu


Peanut butter


Edamame beans


Chicken breast


Greek yogurt


Protein powder


Chickpeas


Salmon

Female specific requirements

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Dietary Fat

Introduction

Fats are a fundamental yet often misunderstood component of a balanced diet. While there is often a prevailing misconception that fats should be limited or avoided, their role in the health and performance of female athletes is paramount. The information below will delve into the significance of fats in the diet, explore various types of fat, provide recommendations for intake, and offer strategies to effectively incorporate fats into the diet of female athletes.

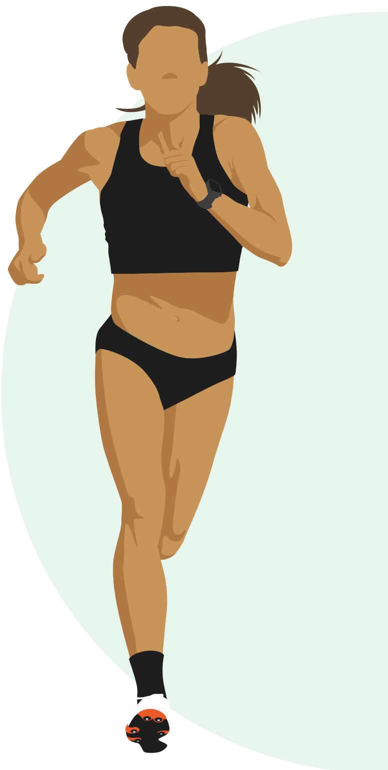
Understanding fats

Fats, scientifically known as lipids, stand alongside carbohydrates and proteins as one of the three macronutrients. Their importance is multifaceted:

Energy source	Fats are an energy dense nutrient, providing 9 kilocalories (kcal) per gram. This dense energy reserve is particularly valuable for athletes engaged in endurance sports. While carbohydrates serve as the primary energy source, fats also provide energy to the working muscles, especially during low to moderate intensity activities.
Hormone production	Fats are essential for the synthesis of steroid hormones, including the main female reproductive hormones, estrogen and progesterone.
Cellular structure	Fats contribute to the formation of cell membranes through phospholipids and cholesterol. These lipids compose the lipid bilayer in cell membranes, which acts as a semi-permeable barrier, maintaining cell boundaries, regulating substrate transportation, and ensuring proper cell function.
Vitamin absorption	Fat-soluble vitamins such as A, D, E and K, require the presence of dietary fats to be effectively absorbed.

Figure 1: Key roles of fat within the body

The role of fat during exercise



One of the primary functions of fat in the body is to store energy for later use. Adipose tissue, also known as body fat, acts as a reservoir of stored energy in the form of triglycerides (Figure 2). Fat can also be stored in the muscle, this is known as intramuscular triglyceride and is an important fuel source during exercise. Compared to males, females have higher intramuscular triglyceride stores in their muscles and are more efficient at using them during exercise. The utilization of fat as an energy source during exercise varies based on exercise intensity and duration.

During low to moderate intensity, steady-state activities such as long-distance running or cycling, the body primarily relies on fat oxidation for energy.

Research has shown that during exercise performed in a fasted state, females oxidize more fat to support the energy needs of exercise in comparison to males. By relying on fat as a primary energy source during low to moderate intensity exercise, the body preserves glycogen for high intensity movements. Slower depletion of muscle glycogen might suggest that female athletes are more fatigue resistant allowing them to perform well in long duration endurance events.

Endurance type training can enhance the body's capacity to use fat as an energy source, even during higher-intensity exercise. Endurance athletes might benefit from undergoing training sessions that are known to increase fat metabolism (i.e., fasted training) during the off-season, where the focus is more on muscle adaptation rather than performance.

Lipid breakdown

The breakdown of lipids is called lipolysis and takes place in the adipose tissue and skeletal muscle

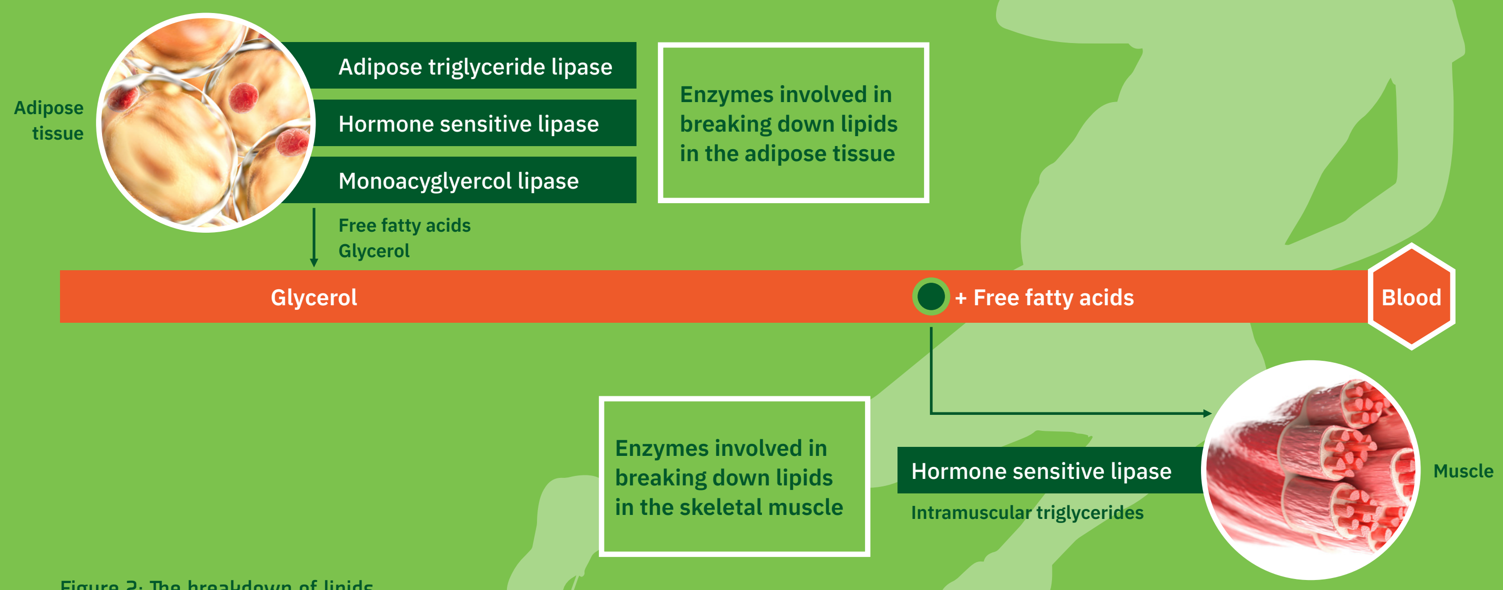


Figure 2: The breakdown of lipids

Types of dietary fats

Dietary fats (i.e., triglycerides) have a backbone composed of a glycerol molecule and attached to this are three fatty acids (Figure 3). They are classified based on their chemical composition (Figure 4).

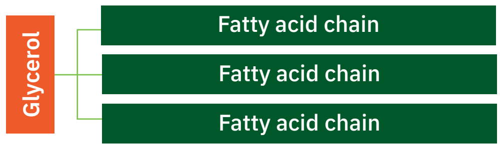


Figure 3: Dietary fat (triglyceride) structure

Saturated fats

These fats are typically solid at room temperature and are prevalent in animal products such as butter, red meat, and dairy products. Excessive consumption of saturated fats can elevate low density lipoproteins (LDL) which can raise the level of 'bad' cholesterol in the blood, therefore limiting saturated fat intake is advised. The American Heart Association advises 5-6% of total calories to come from saturated fat.

Monounsaturated fats

Liquid at room temperature, these fats are found in foods such as olive oil, avocados, and nuts. They are recognized for their heart-healthy attributes and deserve a prominent place in the diet of athletes.

Polyunsaturated fats

The body requires both omega-3 and omega-6 fatty acids, both of which fall into this category. Sources include fatty fish (e.g., salmon, mackerel), flaxseeds, walnuts, and specific vegetable oils. Omega-3 fatty acids possess anti-inflammatory properties beneficial for post-exercise recovery (see below).

Trans fats

Artificial trans fats are created when liquid oils are turned into solid fats, and are known to elevate LDLs and cholesterol levels. They are commonly found in processed and fried foods and should be avoided due to their negative health implications.

Figure 4: Types of dietary fats

Omega-3 Fatty Acids (O3FA)

O3FA have been found to have a variety of potential beneficial effects for health and performance, for example, promoting joint health, managing inflammation, protecting brain health and function, and facilitating muscle recovery. They are therefore of importance for athletes. Despite this, it has been shown that many athletes consume sub-optimal amounts of O3FA within their diet. There are three main types of O3FA which are alpha-linoleic acid (ALA), eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). It is well-established that EPA and DHA, found in sources such as fish, are more readily absorbed by the body while ALA can be converted to EPA and DHA in the body, but this conversion is not highly efficient.

Research has found that EPA may help to mitigate exercise-induced inflammation, potentially expediting recovery. EPA is also associated with bolstering cardiovascular health, essential for an athlete's endurance and overall performance.

O3FA recommendations

There are no established Recommended Dietary Allowance (RDA) or Daily Value (DV) guidelines for O3FA. Various dietary recommendations exist from different health authorities. For example:

- Academy of Nutrition and Dietetics and Dietitians of Canada:
  0.5 grams of EPA + DHA daily
- European Food Safety Authority:
  0.25 grams of EPA + DHA daily
- American Heart Association:
  Two servings of fish each exceeding 3.5 ounces per week

Athletes may require higher O3FA intake in comparison to the general population due to factors such as energy metabolism, training volume and exercise-induced inflammation. In addition, O3FA may be beneficial to athletes during periods of injury or immobilization. Individualized O3FA doses for athletes are recommended because daily requirements vary significantly among athletes, contingent on factors such as gender, body weight, metabolic rate, and training intensity. However, if a standardized dose is required then a daily dose of 1-3 g EPA + DHA may be appropriate.

Athletes aiming to enhance their O3FA levels can do so through a combination of dietary sources and supplements (see Figure 5 and Table 1). Supplements come in various forms, including fish oil (typically in ethyl ester form), krill oil (rich in phospholipids and free fatty acids), and algae oil (a plant-based alternative). For athletes with specific dietary restrictions (e.g., vegetarians, seafood allergy, those who avoid fish), viable alternatives such as seaweed, kelp, algae-fortified foods, or algae-based O3FA supplements can be explored.

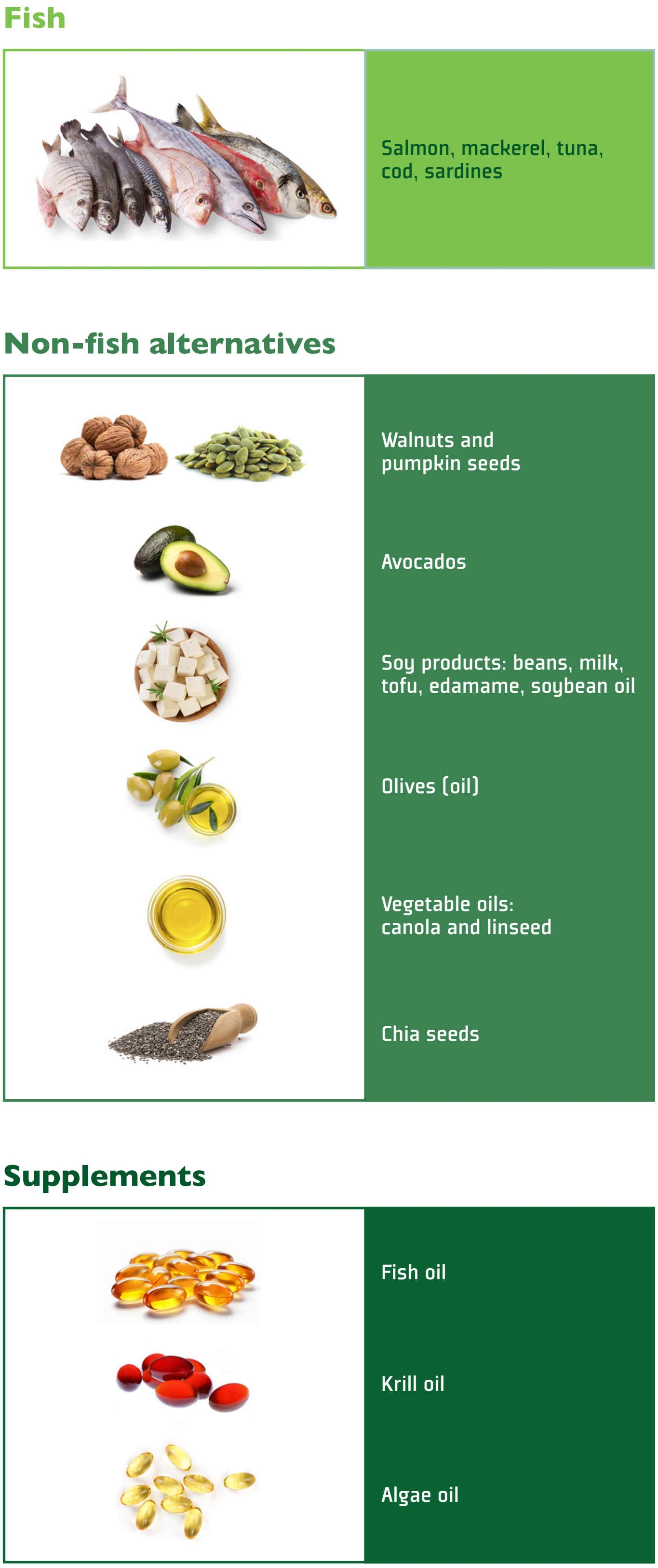


Figure 5: Sources of omega-3 fatty acids

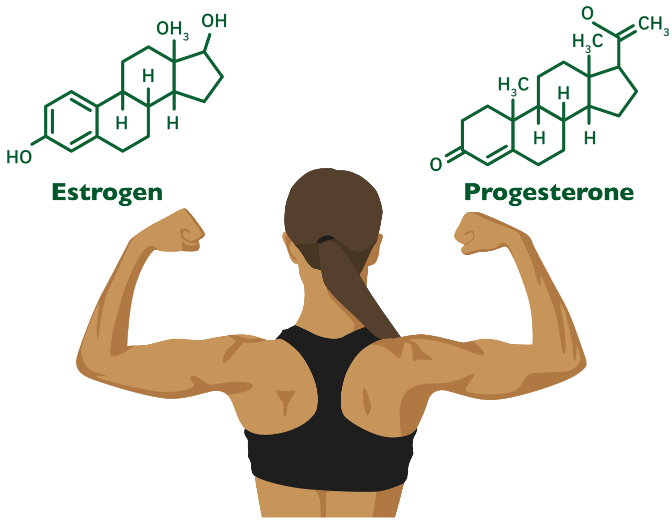
Table 1: Dietary sources of omega-3 fatty acids

	Source	Serving	EPA	DHA	ALA
EPA & DHA sources	Salmon (cooked)	3 ounces	1.2 g	0.6 g	-
	Herring (cooked)	3 ounces	0.9 g	0.8 g	-
	Bluefin tuna (fresh)	3 ounces	0.8 g	0.2 g	-
	Sardines (canned, drained)	3 ounces	0.7 g	0.5 g	-
	Mackerel (cooked)	3 ounces	0.6 g	0.4 g	-
	Salmon (canned, drained)	3 ounces	0.6 g	0.3 g	-
	Sea bass (cooked)	3 ounces	0.5 g	0.2 g	-
	Cod liver oil	1 teaspoon	0.5 g	0.3 g	-
	Trout (cooked)	3 ounces	0.4 g	0.4 g	-
	Oysters (cooked)	3 ounces	0.2 g	0.3 g	-
	Tuna (canned)	3 ounces	0.1 g	0.2 g	-
	Scallops	3 ounces	0.1 g	0.1 g	-
	Shrimp	3 ounces	0.1 g	0.1 g	-
	Lobster	3 ounces	0.1 g	0.1 g	-
ALA sources	Flaxseed oil	1 tablespoon	-	-	7.3 g
	Chia seeds	1 ounce	-	-	5.1 g
	Walnuts	1 ounce	-	-	2.6 g
	Flaxseeds	1 tablespoon	-	-	2.4 g
	Canola oil	1 tablespoon	-	-	1.3 g
	Soybean oil	1 tablespoon	-	-	0.9 g
	Edamame	½ cup	-	-	0.3 g
	Refried beans (canned, drained)	½ cup	-	-	0.2 g

EPA; Eicosapentaenoic acid, DHA; Docosahexaenoic acid, ALA; Alpha-linolenic acid

The role of fat in hormone production

Fats play a pivotal role in the production of estrogen and progesterone, two hormones critical to female physiology. These hormones are synthesized from cholesterol, a lipid. Cholesterol acts as the precursor molecule to produce steroid hormones, including estrogen and progesterone. Specialized cells, primarily in the ovaries and adrenal glands, convert cholesterol into these hormones. Adequate dietary fat intake ensures a sufficient supply of cholesterol, facilitating the body's ability to synthesize estrogen and progesterone. These hormones, in turn, regulate various aspects of the menstrual cycle, reproductive health, and overall well-being in females, highlighting the essential role of dietary fats in hormonal balance and female physiology.



Recommended fat intake for female athletes

The American Dietetic Association recommends that fats should constitute 20-35% of total daily calorie intake. For female athletes, it is imperative to:

- Emphasize sources of healthy fats, including avocados, nuts, seeds, and oily fish
- Limit saturated and trans fats commonly found in processed and fried foods
- Ensure O3FA are incorporated into the diet

Incorporating fats into the diet

Female athletes should prioritize healthy fat sources such as avocados, nuts, seeds, and fatty fish while being vigilant about saturated and trans fat intake (Figure 6). Tailoring fat consumption within a personalized nutrition plan designed to meet an athlete's unique needs can unlock the full potential of fats for female athletes.

Female athletes can seamlessly integrate fats into their diet through various foods and cooking methods:

- Drizzle olive oil on salads and vegetables
- Include a handful of nuts or seeds as a convenient snack, or use as a topping on meals e.g., salads
- Consume oily fish such as salmon
- Utilize avocados as a topping for sandwiches or salads, or as an ingredient in smoothies
- Elevate the nutritional value of breakfast by incorporating nut butter into oatmeal or pairing it with fruit

Summary

Fats play an important role to support the health and performance of all athletes, including females. They serve as a valuable energy source, contribute to cellular structure, aid hormone production and vitamin absorption, and play a crucial role during exercise. Understanding the types of dietary fats and making informed choices can significantly impact an athlete's health and performance. Omega-3 fatty acids potentially offer unique benefits, such as improved joint health and muscle recovery, as well as inflammation reduction, which can be advantageous for female athletes. By following recommended fat intake guidelines and incorporating healthy fats into their diets, female athletes can unlock the full potential of these essential nutrients, supporting their overall health, endurance, and athletic success.

Figure 6: Meals and snacks incorporating 'healthy' fats

DIETARY FAT

Fat:
9 kcal per gram

Primary source of energy during low to moderate intensity, steady state activities e.g., long-distance running or cycling

Role of fat:
- Energy source
- Hormone production
- Cellular structure
- Vitamin absorption

Dietary sources of fat

Saturated fats
Limit consumption to 5–6% of total calories

Butter, Cheese, Eggs, Fatty cuts of meat

Polyunsaturated fats
Includes omega-3 and omega-6 fatty acids

Fish, Sunflower oil, Flaxseeds, Vegetable oils

Monounsaturated fats
Recognised for their positive benefits to heart health

Almonds & pecans, Avocados, Olive oil, Nuts & seeds

Trans fats
Elevate LDLs and cholesterol therefore consumption should be limited

Pastries and pies, Pizza, Fried chicken, Ice cream

Omega-3 fatty acids

May help optimize athletic performance by:
- Promoting joint health
- Managing inflammation
- Protecting brain health and function
- Facilitating muscle recovery

Fish

Salmon, mackerel, tuna, cod, sardines

Non-fish alternatives

- Avocados
- Walnuts and pumpkin seeds
- Soy products: beans, milk, tofu, edamame, soybean oil
- Olives (oil)
- Vegetable oils: canola and linseed
- Chia seeds

Supplements

- Fish oil
- Krill oil
- Algae oil

Micronutrients

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.

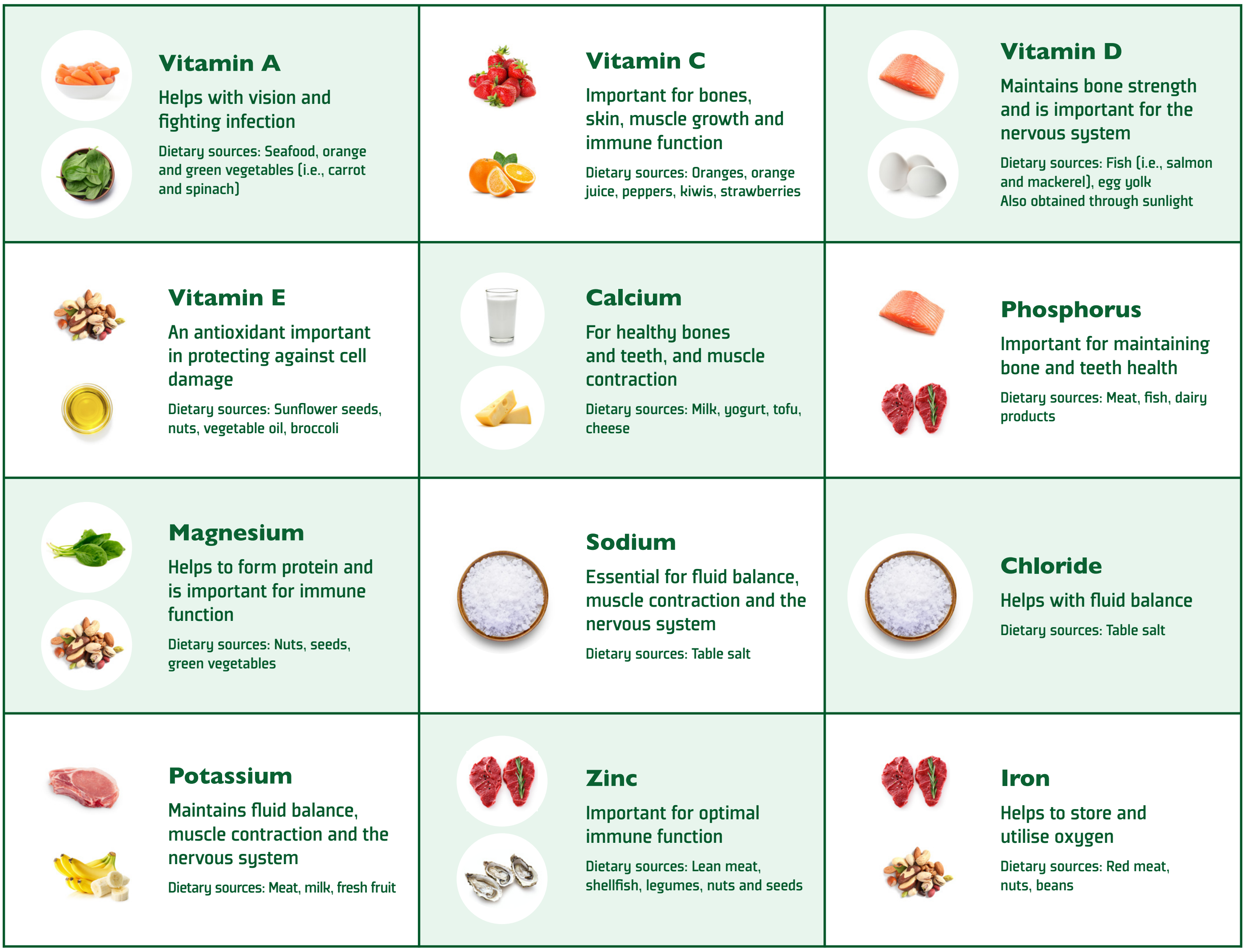


Figure 1: The main functions of micronutrients and common dietary sources

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

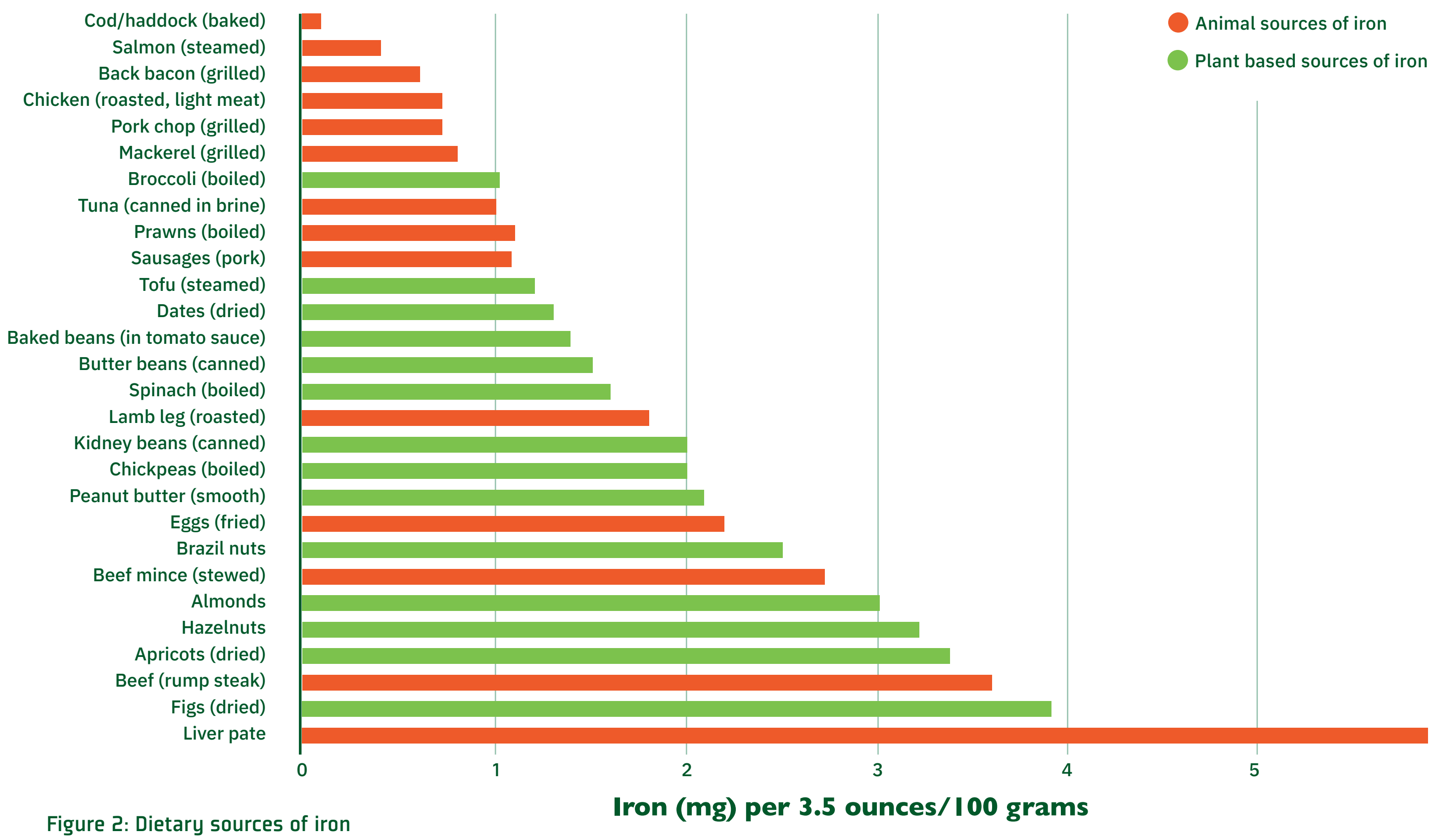


Figure 2: Dietary sources of iron

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.

Enhances iron absorption

Foods containing vitamin C

E.g., oranges, orange juice, peppers, kiwis, strawberries

26 Fe

Consuming iron-rich foods/supplements:

- In the morning
- Within 30 minutes prior to exercise
- Within 30 minutes after exercise

Impairs iron absorption

(if consumed in close proximity to iron-rich foods/supplements)

Foods containing calcium

E.g., milk, yogurt, cheese, tofu

Caffeine

E.g., tea, coffee

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.

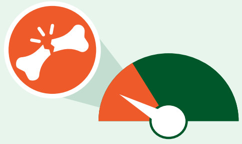
3 Intravenous (IV) iron infusions

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.



Low estrogen levels

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).

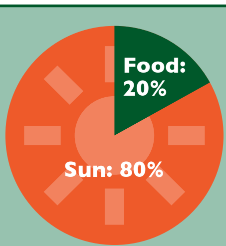
It is estimated that 33-42% of female athletes present with vitamin D insufficiency. Specific to females, vitamin D plays a key role in estrogen production. Therefore, the effects of vitamin D deficiency may also influence menstrual status and fertility, as well as bone health.

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

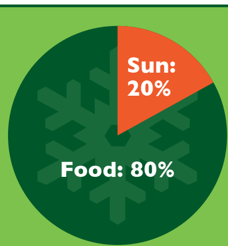
Time: 10am–3pm

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

GATORADE SPORTS SCIENCE INSTITUTE™

Hydration

Introduction

Body water is critical for many bodily processes such as regulating blood volume and blood pressure, and transporting oxygen and nutrients (Figure 1). Another key role is regulating body core temperature, which is important for athletes because during exercise, the working muscles generate heat which causes a rise in body temperature. In response, sweat production occurs and the evaporation of sweat from the surface of the skin cools the body. This bodily process prevents a sharp rise in body core temperature and in turn, reduces the risk of heat illness and any associated heat-related impairments in exercise performance.

Figure 1: The role of water in the body

On average, females have a smaller body size and a higher body fat percentage than males. As adipose (i.e., fat) tissue has a lower percentage of water (~10%) than fat-free mass (~74%), females have a lower overall percentage of body water (~55-60%).

Fluid balance

Sweat losses during exercise vary greatly between and within individuals due to factors such as body mass, exercise intensity and duration, environmental conditions, clothing and equipment, and training and heat acclimation status. Although in general females have lower sweating rates than males, this is usually attributed to their lower body mass and absolute exercise intensities.

Ingesting fluids can offset water losses experienced during exercise. However, when fluid intake is less than sweat loss, a body water deficit occurs, which is known as dehydration. On the other hand, if fluid intake exceeds fluid losses, the body will be in a state of hyperhydration (Figure 2).

Significant dehydration (> 2% body mass losses) has been found to impair aerobic performance in the heat, with greater levels of dehydration (3-4% body mass losses) found to impair aerobic performance in cooler conditions, as well as cognitive performance and technical skill in certain team sports. Therefore, it is important to ensure that athletes are adequately hydrating daily, as well as following sufficient hydration practices pre-, during and post-exercise.

Fluid balance terminology:

Hyperhydration
Excessive body water surplus

Euhydration
Normal baseline body water content

Hypohydration
Excessive body water deficit

Dehydration
Progressive body water loss

Rehydration
Progressive body water gain

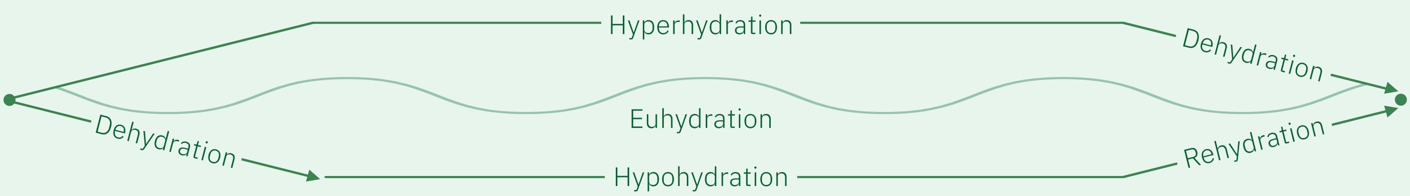


Figure 2: Fluid balance terminology (Greenleaf, 1992)

The information below provides a guide to understanding and meeting daily fluid requirements, spotting the signs of hypohydration, measuring sweat rate, and hydration recommendations for optimal performance.

Daily fluid requirements

Hydration is typically maintained through habitual eating and drinking habits. Both the European Food Safety Authority (EFSA) and the USA's Institute of Medicine (IOM) have published daily water intake recommendations, as shown in Table 1.

Table 1: Total daily water dietary reference intakes values (adequate intakes) for females set by the European Food Safety Authority (EFSA) and the Institute of Medicine (IOM).

Age	EFSA	IOM
9 – 13 years	1.9 L/day ~64 oz/day	2.1 L/day ~71 oz/day
14 – 18 years	2.0 L/day ~68 oz/day	2.3 L/day ~78 oz/day
19 years+	2.0 L/day ~68 oz/day	2.7 L/day ~91 oz/day

Dietary water consumption

In the diet, water is predominantly obtained through consumption of drinking water/beverages (80%) (Figure 3). Some water (20%) is also obtained through the consumption of water-containing foods (Figure 4).


Water


Cow's milk


Dairy free milk alternatives


Sports drink


Fruit juices and smoothies


Soda


Coffee


Tea


Energy drinks


Protein shakes

Figure 3: Types of common beverages

50% 75% 100%

Ground beef
Feta cheese
Lean steak

Legumes
Salmon
Ice cream
Chicken breast

Banana
Avocado
Cottage cheese
Potato (baked)
Shrimp

Fruit juice
Yogurt
Apples
Grapes
Oranges
Carrot
Broccoli
Pineapple

Milk
Strawberries
Lettuce
Cabbage
Celery
Spinach
Pickles

Figure 4: Approximate water content of foods

Important considerations for athletes

Daily fluid requirements may vary day-to-day depending on a variety of factors including how much the athlete sweats during exercise, daily life demands, and environmental conditions. Importantly for athletes, exercise type and intensity can alter fluid needs. Therefore, it is recommended to:

1 **Monitor the hydration status of athletes**

2 **Recognize and educate athletes on the signs of dehydration**

3 **Provide fluid recommendations depending on an athlete's individual needs**

Daily monitoring of hydration

Indicators of hydration status include changes in daily body mass, a measure of urine (i.e., color, volume or concentration), and feelings of thirst.

Specific guidelines for monitoring each indicator are outlined below:

Body mass (weight)

Take daily body mass measurement (ideally nude) at the same time of day on consecutive days, and ideally before any activity or consumption of food/drinks. If daily body mass loss is > 1%, compared to baseline euhydrated values, it may indicate a likelihood of dehydration.

A cost/benefit analysis should be performed before introducing daily measures of body mass. If implemented, female athletes should be educated on the reasons behind why this measurement is being taken.

Urine

Assessing urine volume and color offers a practical and cost-effective method to estimate hydration status. Reduced urine output and/or a darker urine color (indicative of higher concentration) can indicate dehydration. The urine color scale can help to categorize hydration status. Urine specific gravity (USG) and osmolality (UOsm) can also be used to estimate hydration status, as per Table 2.

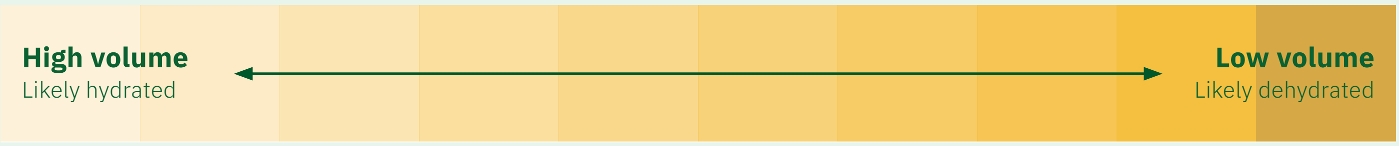


Figure 5: Urine color scale

Table 2: Hydration classification according to urine USG and UOsm values

Classification athlete likely:	Urine USG value	Urine osmolality value (mOsm/kg)
Euhydrated	<1.020	<700
Minimally dehydrated	1.020 – 1.024	700 – 900
Dehydrated	>1.024	>900

(Kenefick & Cheuvront, 2012)

Thirst

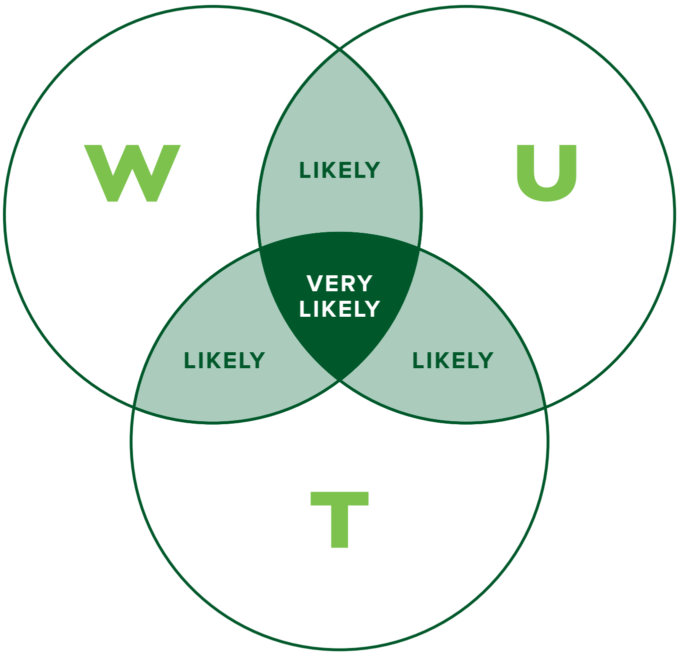
Thirst signals the body's need for fluids and can be an initial sign of dehydration. However, the absence of thirst doesn't guarantee the absence of dehydration. Menstrual cycle phase may alter thirst perception, during the luteal phase the rise in estrogen can decrease the osmotic threshold for thirst.

How thirsty do you feel now?

Figure 6: Thirst scale

Integrated methods for monitoring daily hydration status

Body mass (weight), urine and thirst measures in isolation cannot definitively prove if an athlete is hydrated or dehydrated. The weight, urine colour and thirst (WUT) venn diagram provides a practical hydration assessment tool. The presence of any two indicators suggests a potential for dehydration, while the presence of all three strongly indicates the likelihood of dehydration. Consistent tracking is needed to provide a more accurate picture of hydration status.



W = Weight
U = Urine
T = Thirst

Figure 7: 'WUT' venn diagram (Cheuvront & Sawka, 2006)

Hydration recommendations pre-, during and post-exercise

Pre-exercise

Athletes should begin any type of physical activity in a hydrated state, while also ensuring that they do not feel bloated, or the need to urinate frequently. It is recommended that athletes consume 5-7 milliliters (mL) of fluid per kilogram (kg) of body mass (mL/kg), 4 hours before the start of exercise. If no urine is produced, or if urine is dark in color, advise athletes to drink an additional 3-5 mL/kg in the 2 hours before exercise starts. A beverage containing electrolytes (i.e., a sports drink) will help the body to retain the fluids consumed.

Use the calculations below to determine pre-exercise fluid recommendations for individual athletes:

4 hours prior to exercise:

_______ body mass (kg) * 5 mL = _______ mL **70 kg = 350 mL**

TO

_______ body mass (kg) * 7 mL = _______ mL **70 kg = 490 mL**

2 hours prior to exercise:

(if needed, i.e., if urine is low in volume and/or dark in color)

_______ body mass (kg) * 3 mL = _______ mL **70 kg = 210 mL**

TO

_______ body mass (kg) * 5 mL = _______ mL **70 kg = 350 mL**

Orange = Example

During exercise

Acute changes in body mass over the course of exercise can be used to measure fluid loss, and in turn the rate of sweat loss per hour (i.e., sweat rate) can be calculated. This information will then inform fluid recommendations during exercise to prevent significant dehydration (> 2% body mass losses). Follow the steps below to calculate sweat rate.

Sweat rate calculator

Step 1: Calculate sweat loss

Pre-exercise body mass
_______ kg
70 kg

−

Pre-exercise body mass
_______ kg
69.2 kg

+

Fluid intake
_______ L
0.5 L

=

Sweat loss
_______ L
1.3 L

Step 2: Exercise time

_______ h
1 h

Step 3: Calculate sweat rate

Sweat loss
_______ L
1.3 L

÷

Exercise time
_______ h
1 h

+

Sweat rate
_______ L/h
1.3 L/h

Orange = Example

Recognizing dehydration

Due to the large variability in sweat rate between and within athletes, it is advised to measure sweat rates in different conditions to inform personalized fluid recommendations. Having personalized hydration plans will help prevent dehydration. However, it is always important for athletes and practitioners to be able to recognize the signs and symptoms of dehydration.

Recognize the signs of dehydration

- Headache
- Urine low in volume and/or dark in color
- Extreme thirst
- Lightheaded
- Nausea
- Mental & physical fatigue

To increase fluid intake during exercise, schedule regular fluid breaks (if possible), especially in sessions that are > 60 minutes, of high-intensity, and/or in hot and humid conditions.

High sweat sodium concentrations

When sweating occurs, electrolytes are also lost from the body. One electrolyte of interest is sodium because the concentration of sodium in sweat also varies between individuals. Athletes with high sweat sodium concentrations can often be identified if white salt stains appear on clothing during exercise, or they can be identified through measuring sweat sodium concentrations, however this requires specialist equipment. For athletes with high sweat sodium concentrations, consuming a beverage that contains sodium (such as a sports drink) will help to replace the sodium lost in sweat and it will also stimulate drinking. Sports drinks also contain carbohydrates which can help with the uptake of fluid in the gut, and support physical and cognitive performance.

The effect of both sex and menstrual cycle phase on sweating rate and composition

Both sex and menstrual cycle can have an impact on sweating rate and/or composition, which can be seen in Table 3.

Table 3: The effect of both sex and menstrual cycle phase on sweating rate and composition

	Sex differences	Menstrual cycle
Sweating rate	Women have a lower maximal sweating capacity (i.e., at very high workloads and in hot, dry environments). Otherwise, lower sweating rates observed in women can usually be attributed to lower body mass and absolute workloads. Women have lower output per gland and higher heat-activated sweat gland density. This translates to greater sweating efficiency, which may lead to less wasted sweat (drippage) in humid environments.	During the luteal phase there is an increase in the threshold (body core temperature set point) for the onset of sweating and/or decreased sweating sensitivity. However, there are no differences in whole body sweat rates during exercise across menstrual cycle phases.
Sweating composition	Women tend to have slightly lower sweat $[Na^+]$ and $[Cl^-]$ as a population, but no differences when accounting for absolute workload and/or sweating rate.	None

While there are some observed differences in sweating rate and composition between women and men, these variations are not significant enough to warrant different recommendations based on sex.

Post-exercise

Rehydration is an important part of the post-exercise recovery process. The aim is for athletes to replace any fluid and electrolyte losses that occurred during exercise, before the next exercise bout begins. In most situations, water and sodium can be replaced with normal eating and drinking practices. Drinking a beverage with sodium, or eating sodium-containing foods, will help replace sweat sodium losses, stimulate thirst, and retain the ingested fluids. Athletes are also advised to sip, and not chug, fluids. The replacement of both fluid and sodium should be combined with other recovery priorities (i.e., carbohydrate to replenish glycogen stores and protein to help muscles repair/adapt).

If dehydration is severe (> 5% body mass loses), or if rapid rehydration is needed (i.e., < 24 h before next exercise bout), the recommendation is for athletes to drink 1.2 - 1.5 L of fluid for each 1 kg of body mass loss.

Calculating post-exercise fluid requirements

Pre-exercise body mass		Post-exercise body mass		Body mass loss
______ kg	−	______ kg	=	______ kg
70 kg		69.2 kg		0.8 kg

Body mass loss				Fluid to consume post-excercise
______ kg	×	120-150%	=	______ L
0.8 kg				1-1.2 kg

Orange = Example

Conclusion

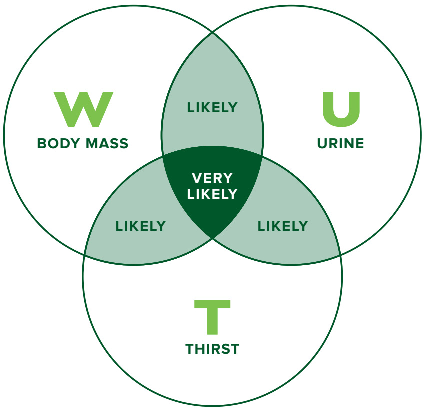
Optimal hydration is important for both health and performance. It is important to monitor the hydration status of athletes, incorporate personalized hydration plans, and enable strategic fluid intake pre-, during and post-exercise. Fluid intake can come from a variety of food and beverages. Table 4 provides practical advice which can be used with athletes on when to ingest different types of beverages. Finally, it is essential that practitioners and athletes recognize the signs of symptoms of dehydration.

Table 4: Practical advice regarding the use of common beverages

Common beverages	Practical advice to use with athletes
Water	• Drink water with all meals • Keep a drinks bottle with you throughout the day • Drink 5-7 ml of water per kg of body mass 4 hours before the start of exercise
Milk	• Avoid close to the start of exercise • Good option as a post-exercise recovery beverage
Sports Drink	• Good choice for before, during and after intense or prolonged exercise • Practice consuming during training sessions, prior to using during competition
Fruit Juices	• To reduce the risk of stomach upset, do not consume too close to exercise or during exercise
Soda	• Enjoy on social occasions • If the soda contains caffeine, avoid consuming late in the evening as it might negatively impact sleep • Zero sugar options recommended if body composition is a priority
Tea (hot/iced), coffee	• Consider coffee 1 hour before exercise to support performance benefits • Avoid after mealtime occasions because caffeine can inhibit iron absorption • Avoid late at night because sleep will likely be impacted by caffeine
Energy drinks (caffeinated, high sugar)	• Avoid drinking late in the evening because energy drinks may disturb sleep • Do not over consume • May be considered in the hour before exercise
Protein recovery shakes	• Ingest post-exercise to maximize adaptive response • Contributes to fluid, electrolyte, and muscle recovery

HYDRATION

Daily monitoring of hydration



Body mass
Daily body mass loss >1% may indicate likelihood of dehydration

Urine
Reduced urine output and/or a darker urine color can indicate dehydration

Thirst
Feelings of thirst may be an initial sign of dehydration

Presence of two indicators: Potential of dehydration

Presence of three indicators: Strong indication of dehydration

Hydration recommendations around exercise

4 hours before exercise	5–7 mL of fluid per kg of body mass
2 hours before exercise	3–5 mL of fluid per kg of body mass (if urine is dark and/or low volume)
During exercise	Use a personalized hydration plan to limit dehydration to 2% of body mass
After exercise	Replace fluid/electrolyte losses through normal drinking practices 120–150% body mass loss if dehydration is severe/if rapid rehydration is needed

Does sex or menstrual cycle phase influence sweating rate and/or composition?

	Sex differences	Menstrual cycle
Sweating rate	Women have a lower maximal sweating capacity (i.e., at very high workloads and in hot, dry environments). Otherwise, lower sweating rates observed in women can usually be attributed to lower body mass and absolute workloads. Women have lower output per gland and higher heat-activated sweat gland density. This translates to greater sweating efficiency, which may lead to less wasted sweat (drippage) in humid environments.	During the luteal phase there is an increase in the threshold (body core temperature set point) for the onset of sweating and/or decreased sweating sensitivity. However, there are no differences in whole body sweat rates during exercise across menstrual cycle phases.
Sweating composition	Women tend to have slightly lower sweat $[Na^+]$ and $[Cl^-]$ as a population, but no differences when accounting for absolute workload and/or sweating rate.	None

Pre-exercise Fueling

Introduction

Fueling optimally before training or competition will help athletes to perform at their best. It is important for female athletes to have knowledge of which types of foods are recommended to ingest before exercise, as well as which foods to limit. Pre-exercise nutrition strategies should be developed with athletes on an individual basis. It is recommended that athletes practice these strategies prior to training so that they know what works for them when it comes to a major competition, match or race. This will help athletes to feel confident in their choices so that they feel ready to perform at their best. The information below will explain key nutrition considerations for pre-exercise fueling to promote optimal performance in key training sessions or competition. It should be noted that currently, the recommendations for pre-exercise fueling do not differ between females and males.

Nutrition considerations: 1-2 days prior to exercise

Carbohydrate is stored in the body as glycogen, predominantly in the skeletal muscles and liver (Figure 1), however the body can only store a limited amount. During exercise, carbohydrates (in the form of glycogen and glucose) are often the main energy source for working muscles, with the contribution of carbohydrate to energy metabolism increasing as exercise intensity increases. It is important that athletes maximize their glycogen stores prior to exercise to provide working muscles with sufficient energy, which will help to delay fatigue and optimize performance. This is done by consuming carbohydrate-rich foods, and is particularly important prior to exercise that is of long duration and/or high intensity. The following information will discuss how athletes can optimize their glycogen stores prior to a key training session or competition (which will be referred to simply as 'exercise' from here onwards).

Skeletal muscles
~400
grams of glycogen
Provides energy to working muscles

Liver
~100
grams of glycogen
Maintains blood glucose levels

Figure 1: Glycogen storage within the body

Pre-exercise carbohydrate intake

Two strategies which can help to maximize glycogen stores in the 24-48 hours prior to exercise, and promote high carbohydrate availability during exercise, are:

1. **Rest/low intensity, short duration exercise**
2. **High carbohydrate intake**

For most sports, carbohydrate intakes of ~6-8 grams per kg of body mass (g/kg BM) for 24 hours prior to exercise, combined with adequate rest and recovery, will be sufficient to promote high carbohydrate availability during key training sessions/competition. In some cases, carbohydrate intakes of >8 g/kg BM may be required, such as for endurance type events lasting >90 minutes.

Table 1: Recommended carbohydrate intake for different types of activity

Type of activity	Recommended carbohydrate intake
Endurance events (lasting >90 mins)	**8-12 g/kg BM/day** 36-48 hours prior
Most sports	**6-8 g/kg BM/day** 24 hours prior

Practical solutions for increasing carbohydrate intake:

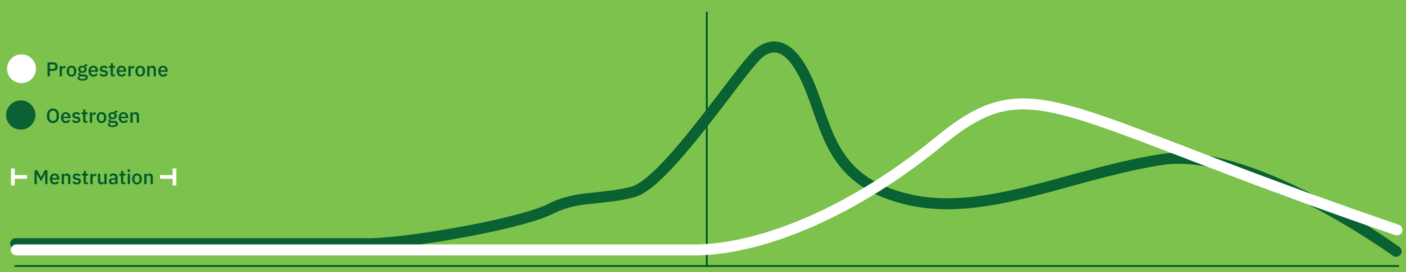
Achieving high carbohydrate intakes can be difficult for some female athletes, in particular for those who have habitual daily energy intakes <2000 kcal. Some practical solutions to help athletes increase their carbohydrate intake include:

- Consuming carbohydrate in liquid form e.g., smoothies, fruit juice, sports drinks, milk-based drinks
- Consuming 'simple' carbohydrates which are more easily digested e.g., white bread/pasta/rice
- Consuming small snacks often as opposed to large meals
- Including higher carbohydrate vegetables within meals e.g., potatoes, corn, parsnips, peas, squash
- Adding beans and legumes into meals e.g., lentils, black beans, pinto beans, kidney beans
- Consuming high carbohydrate snacks e.g., granola bars, bananas, rice cakes

Considerations

Muscle glycogen storage

There is some research, albeit limited, to suggest that females have lower muscle glycogen storage capacity than males. In addition, there may be differences in muscle glycogen storage during different phases of the menstrual cycle (Figure 2). If carbohydrate intake is high, similar levels of resting muscle glycogen concentration can be achieved between the different phases. It is currently unknown whether different forms of hormonal contraceptives impact muscle glycogen storage.



Follicular phase

There may be an increased risk of reduced resting muscle glycogen concentrations if carbohydrate intake is sub-optimal

Luteal phase

When carbohydrate intake is sub-optimal, glycogen storage appears to be more effective during this phase in comparison to the follicular phase

Figure 2: Muscle glycogen storage during the menstrual cycle

Liver glycogen

Liver glycogen stores are reduced by ~50% after an overnight fast, which is a key consideration if exercise start time is earlier in the day. This highlights the importance of optimal nutrition preparation the day prior to exercise, as well as the morning of.

Nutrition considerations: 1-4 hours prior to exercise

It is recommended for athletes to consume a carbohydrate rich meal containing 1-4 grams of carbohydrate per kg of body mass (g/kg BM) in the 1-4 hours before exercise begins (Table 2). The upper end of the recommendations is most relevant for long duration (>90 min), high-intensity endurance events where performance is the primary objective.

Table 2: Carbohydrate recommendations in the 1-4 hours prior to exercise, in relation to body mass

Body mass		Grams of carbohydrate			
kg	lb	1 g/kg BM	2 g/kg BM	3 g/kg BM	4 g/kg BM
45	99	45	90	135	180
50	110	50	100	150	200
55	121	55	110	165	220
60	132	60	120	180	240
65	143	65	130	195	260
70	154	70	140	210	280
75	165	75	150	225	300
80	176	80	160	240	320
85	187	85	170	255	340
90	198	90	180	270	360
95	209	95	190	285	380
100	221	100	200	300	400
105	232	105	210	315	420
110	243	110	220	330	440

Carbohydrate content of different foods, which could be consumed in the 1-4 hours pre-exercise:

Sweet potatoes
Serving size: 1 cup
Carbohydrate: ~30 g
Fiber: ~4 g

Standard potatoes
Serving size: 1 cup
Carbohydrate: ~26 g
Fiber: ~3 g

Couscous
Serving size: 1 cup
Carbohydrate: ~56 g
Fiber: ~5 g

Pasta
Serving size: 1½ cups
Carbohydrate: ~50 g
Fiber: ~7 g

Gatorade Thirst Quencher
Serving size: 20 oz (1 bottle)
Carbohydrate: ~30 g
Fiber: 0 g

Rice
Serving size: 1 cup
Carbohydrate: ~46 g
Fiber: ~3 g

Banana
Serving size: 1 medium
Carbohydrate: ~30 g
Fiber: ~2 g

Oats
Serving size: ½ cup
Carbohydrate: ~30 g
Fiber: ~4 g

Bread
Serving size: 2 slices
Carbohydrate: ~30 g
Fiber: ~5 g

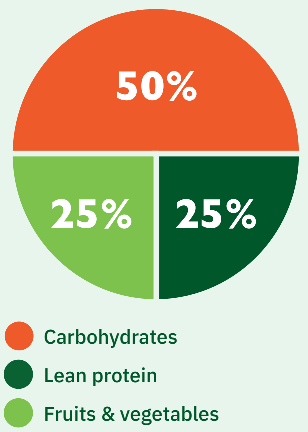
Achieving pre-exercise carbohydrate recommendations

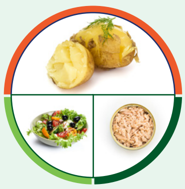
The pre-exercise carbohydrate recommendation of 1-4 g/kg BM encompasses a range, which allows for individual preferences. For example, if an athlete struggles to eat a large amount close to exercise then they may want to consume 2 g/kg BM carbohydrate ~3-4 hours before exercise. On the other hand, another athlete may prefer to have a large meal close to exercise, therefore they may consume 3 g/kg BM carbohydrate in the ~1-2 hours before exercise. Both strategies still meet the pre-exercise carbohydrate recommendations, while also catering for personal preferences. Figure 3 shows how the carbohydrate content of a meal can be adapted.

Figure 3: Meals containing 1–4 g/kg BM carbohydrate (based on a 132 lb / 60 kg female)

Guide for plate portion

In practical terms, an athlete's pre-exercise meal should have at least one source of good quality carbohydrate as a significant part (ideally at least 50%) of their meal. Some ideas for pre-exercise meals using this principle can be seen below:

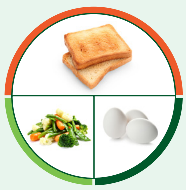




Baked potatoes with protein based topping and small salad

Rice with fish and vegetables

Pasta with protein and vegetable based sauce



Toast with eggs and roasted vegetables

Foods to limit or avoid?

High fat foods

Consuming high fat foods prior to exercise can cause stomach discomfort during exercise (e.g., bloating, gas, abdominal pain) because fat slows the rate at which food is emptied from the stomach. Encourage athletes to limit the amount of high fat food in their pre-exercise meal e.g., processed meats, fried foods, creamy sauces, cheese, and pastries.

High fiber foods

Consuming too much fiber prior to exercise may also cause stomach discomfort during exercise. This is because fiber is slow to empty from the stomach, which means that it takes the body longer to digest it. See Figure 4 for examples of foods high in fiber.

Figure 4: Examples of foods high in fiber

If an athlete experiences gastrointestinal symptoms when beginning exercise, choosing lower fiber foods (e.g., white bread/pasta/rice) in their pre-exercise meal may help to alleviate symptoms. It is important to note that fiber is a very important part of an athlete's diet. Therefore, even if an athlete experiences gastrointestinal symptoms during exercise, fiber should only be reduced strategically around exercise and not eliminated entirely from their diet.

Nutrition considerations: 60 minutes prior to exercise

In the hour prior to exercise, some athletes may wish to consume an additional snack. For example, this may be just before or just after their warm-up. It is recommended that this snack contains ~30-60 grams of easily digestible carbohydrates. For example:

Gatorade Thirst Quencher (20 oz)	Large banana	Gatorade Gx pod (mixed with water)	Single serve Gatorade Thirst Quencher powder (mixed with water)	2 slices white bread with jam	3-4 rice cakes with honey
21g carbohydrate	~25-30g carbohydrate	21g carbohydrate	34g carbohydrate	~35g carbohydrate	~30g carbohydrate

Options can be mixed and matched to meet carbohydrate recommendations

Top tips for pre-exercise fueling

- Encourage athletes to practice competition fueling around training sessions or lower priority competitions
- Provide education when athletes are travelling, as food options may not be as readily available
- Focus on foods that are easily digestible to reduce the risk of gastrointestinal problems (e.g., bloating, discomfort, reflux)
- Encourage athletes to consume familiar foods pre-exercise
- Tailor meal and snack options to meet individual preferences

1-2 days before

Endurance events (lasting >90 mins)

8-12 g/kg BM/day

36-48 hours prior

Most sports

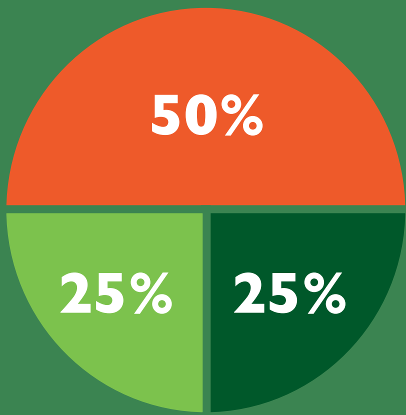
6-8 g/kg BM/day

24 hours prior

1-4 hours before

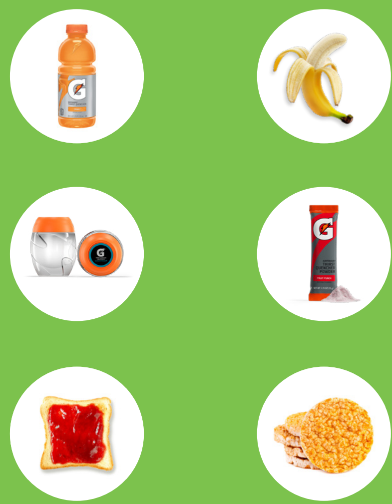
Meal containing 1-4 g of carbohydrate per kg of body mass

Carbohydrate content at least 50% of meal



60 min before

30-60 g of easily digestible carbohydrates



High carbohydrate options to include in pre-exercise meals


Sweet potatoes


Standard potatoes


Couscous


Pasta


Gatorade Thirst Quencher


Rice


Banana


Oats


Bread

Practical solutions for increasing carbohydrate intake in female athletes

- Consume carbohydrate in liquid form e.g., smoothies, fruit juice, sports drinks, milk-based drinks
- Consume small snacks often as opposed to large meals
- Add beans and legumes into meals e.g., lentils, black beans, pinto beans, kidney beans
- Consume ‘simple’ carbohydrates which are more easily digested e.g., white bread/pasta/rice
- Include higher carbohydrate vegetables within meals e.g., potatoes, corn, parsnips, peas, squash
- Consume high carbohydrate snacks e.g., granola bars, bananas, rice cakes

Fueling During Exercise

Introduction

Fueling optimally during exercise can help athletes to increase exercise capacity, improve exercise performance and skill execution, and delay fatigue. It is important for female athletes to understand how they can meet fueling requirements, which differ depending on exercise duration and intensity. The information below will explain key considerations for fueling during exercise. It should be noted that the recommendations currently do not differ between females and males.

Fuel use during exercise

Carbohydrate and fat are both important fuels during exercise, with the contribution of carbohydrate to energy metabolism increasing as exercise intensity increases. There are limited stores of endogenous carbohydrate (i.e., glycogen) within the body, and these stores reduce during exercise when they are used for energy. Glycogen stores will become reduced at a quicker rate during higher intensity exercise (Figure 1), which limits the rate of carbohydrate oxidation. Consuming carbohydrate during exercise (i.e., exogenous carbohydrate) provides additional fuel to be used, which helps to maintain carbohydrate oxidation rates, and in turn delay fatigue and maintain performance.

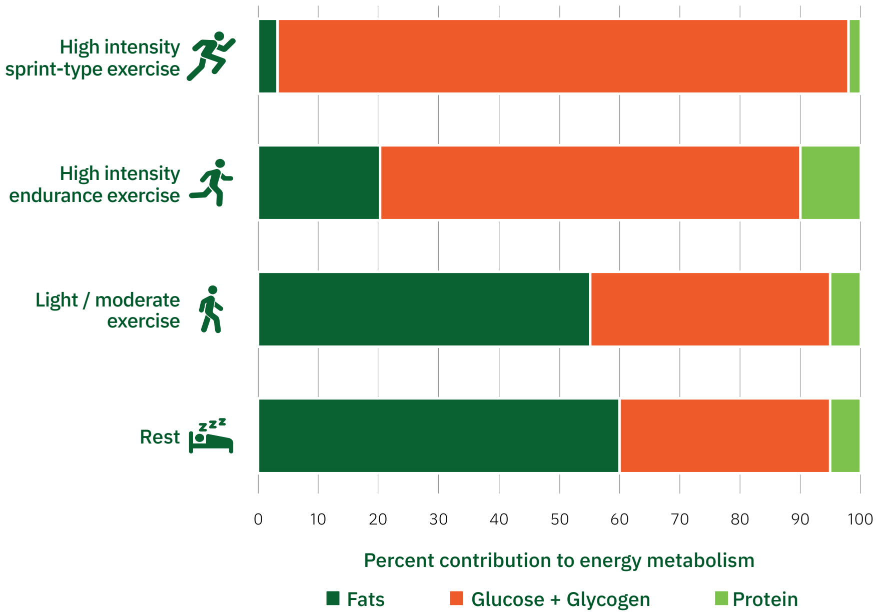


Figure 1: Substrate metabolism at rest and during different exercise types and intensities

Potential benefits of optimal fueling during exercise

Increased exercise capacity

Improved performance

Maintain carbohydrate oxidation

Prevent hypoglycemia

Carbohydrate oxidation rates: females vs males

Research has found that females have lower rates of carbohydrate oxidation and higher rates of fat oxidation during fasted endurance exercise compared to males. These sex differences in substrate metabolism might be due to many factors such as higher maximal oxygen uptake, greater muscle mass, and lower estrogen levels in males, although the exact mechanisms remain unclear. However, when carbohydrate is consumed during exercise, these sex differences in substrate metabolism are not seen. In other words, both males and females oxidize ingested carbohydrate at the same rate. Therefore, currently there are no sex-specific carbohydrate recommendations for during exercise.

Carbohydrate recommendations during exercise

Exercise duration:
< 30 minutes
No carbohydrate necessary

During exercise that is < 30 minutes, muscle glycogen is not a limiting factor for performance. It is therefore not necessary for athletes to consume carbohydrate during exercise lasting < 30 minutes, especially if they are optimally fueled beforehand, or have time to refuel post-exercise.

Exercise duration:
30-75 minutes
Small amount of carbohydrate OR carbohydrate mouth rinse

During exercise lasting 30-75 minutes, athletes may benefit from either a small amount of carbohydrate intake, or a carbohydrate mouth rinse, especially if the exercise is high intensity. Carbohydrate mouth rinsing involves athletes swilling a carbohydrate-containing solution in their mouth (e.g., a sports drink) for 5-10 seconds, which they then spit out. The exact mechanisms remain unclear, but it is likely that the carbohydrate (energy) is detected by receptors in the oral cavity, which activates certain brain regions, causing improved motor drive and/or motivation. During shorter duration exercise bouts, carbohydrate mouth rinsing has been shown to produce very similar performance improvements as those seen when the carbohydrate is actually consumed. The choice between swallowing the carbohydrate solution or expectorating the solution depends on the practicalities of the sport the athlete is competing in, as well as individual preferences.

Exercise duration:
1-2 hours
30-60 grams of carbohydrate per hour

There is extensive research to show that during exercise lasting 1-2 hours, consuming 30-60 grams of carbohydrate per hour (g/h) can improve performance. If the exercise is longer in duration (e.g., close to 2 hours) and/or high intensity, then athletes should aim for the upper end of the recommendation. When athletes are consuming carbohydrate at a rate of < 60 g/h, single sources of rapidly oxidized carbohydrate (e.g., glucose or sucrose) can be ingested.

Exercise duration:
2-3 hours
60-90 grams of carbohydrate per hour

Carbohydrate intake becomes even more important when exercise duration extends beyond 2 hours, in order to prevent a decrease in performance. It is recommended that athletes consume carbohydrate at rates > 60 g/h, and up to 90 g/h for exercise durations > 2.5 hours. This should be in the form of multiple transportable carbohydrates (see below).

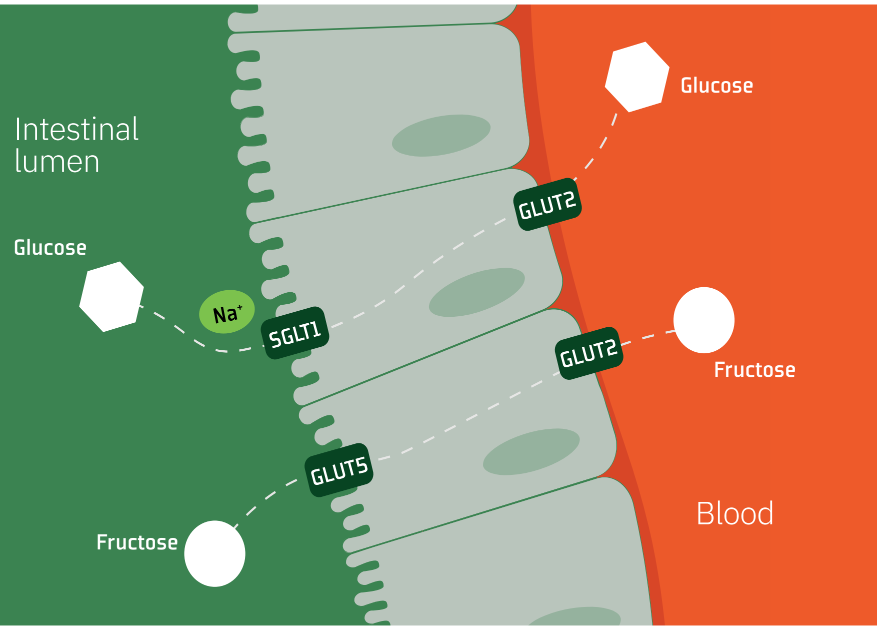
Multiple transportable carbohydrates explained

Carbohydrates are taken up and absorbed by the body using a variety of transporters located in the intestines. However, exogenous carbohydrate oxidation is limited by the rate at which carbohydrates can be absorbed, with intestinal transporters becoming saturated at carbohydrate intakes of ~60 g/h. Therefore, when carbohydrate is consumed at a rates of up to 60 g/h, single sources of carbohydrate can be utilized (e.g., glucose, sucrose).

Consuming multiple transportable carbohydrates (i.e., carbohydrates which use different intestinal transporters), like glucose and fructose, can enhance carbohydrate absorption and utilization compared to a single carbohydrate source. For example, glucose and fructose use different intestinal transporters: glucose uses sodium-glucose cotransporter 1 (SGLT1), which is independent of the transporter that fructose uses, glucose transporter 5 (GLUT5). Therefore, co-ingesting carbohydrates that use different transporters results in higher total carbohydrate oxidation rates, which is beneficial for prolonged or intense endurance exercise (i.e., when carbohydrate intakes of > 60 g/h are required). In addition, ingesting multiple transportable carbohydrates has been shown to increase fluid intake in the intestine in comparison to ingesting a single carbohydrate source.

Absorption of glucose and fructose

In practical terms, it is recommended that athletes consume a 2:1 ratio of glucose:fructose when consuming carbohydrate at rates > 60 g/h. This can be achieved by consuming sports drinks or gels which contain a combination of glucose and fructose. Overall, consuming multiple transportable carbohydrates is an effective strategy for maximizing carbohydrate utilization for prolonged exercise.



Carbohydrate intake recommendations during exercise

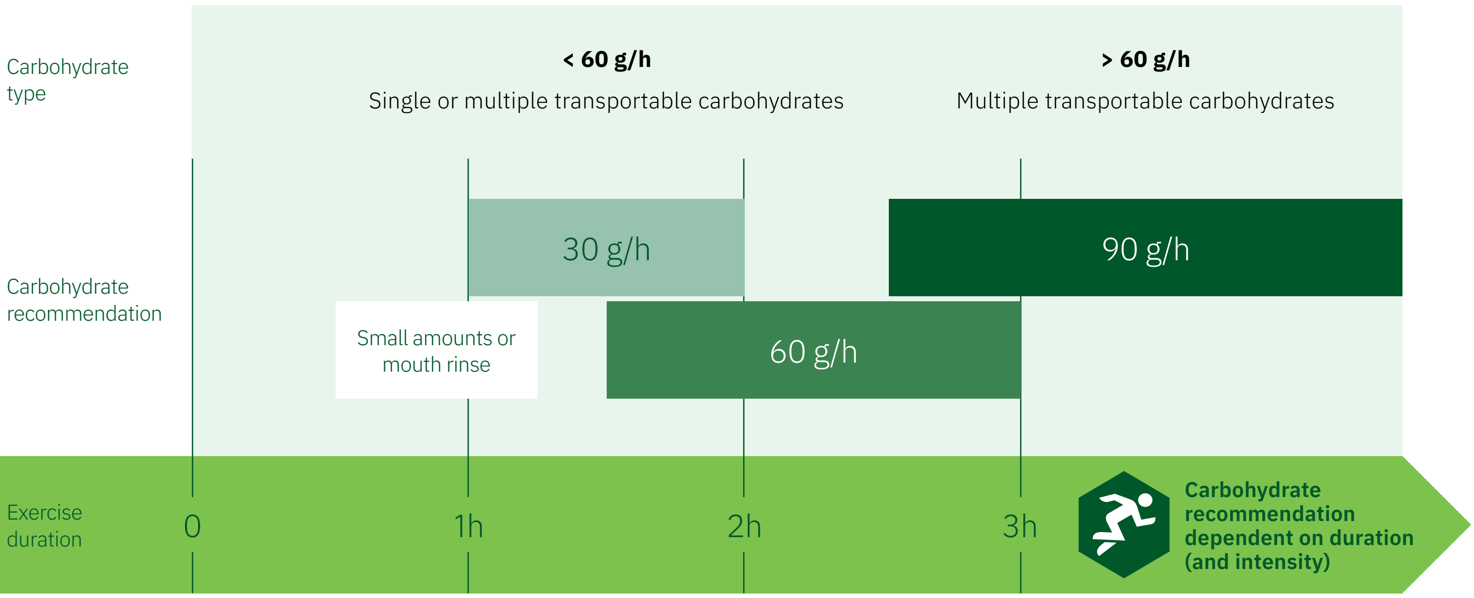


Figure 2: Carbohydrate intake recommendations during exercise
Adapted from Jeukendrup (2014)

Sources of carbohydrate

Carbohydrate can be consumed during exercise in a variety of forms (Figure 3), with no differences in carbohydrate oxidation or performance outcomes seen between different forms. If a solid food option is chosen, then it should ideally be low in fat, protein, and fiber to avoid any gastrointestinal issues.

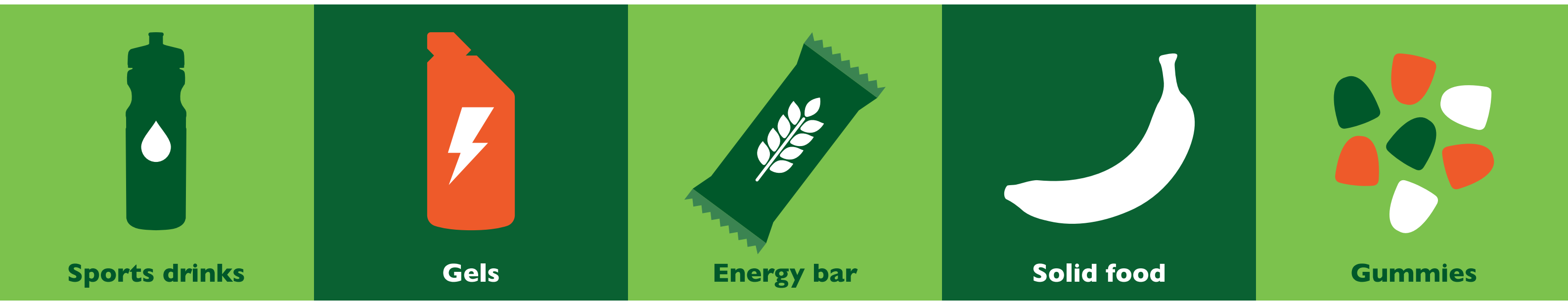


Figure 3: Different forms of carbohydrate

Gastrointestinal complaints during exercise

It has been shown that ~30-50% of athletes experience gastrointestinal complaints during exercise. Early research suggested that prevalence of exercise-associated gastrointestinal symptoms was greater in female athletes vs. male athletes. However, more recent investigations have not seen any differences between genders. Gastrointestinal complaints can be classified into upper and lower abdominal symptoms:

Upper abdominal symptoms	Lower abdominal symptoms
Reflux/heartburn	Intestinal/lower abdominal cramps
Belching	Side ache/stitch
Bloating	Flatulence
Stomach pain/cramps	Urge to defecate
Vomiting	Diarrhea
Nausea	Intestinal bleeding

Potential causes

There are three potential causes of gastrointestinal symptoms during exercise which are:

- Physiological (reduced blood flow to the gut)
- Mechanical (repetitive gut jostling e.g., running)
- Nutritional

Nutritional causes can include:

- Consuming high fiber foods too close to exercise may lead to bloating, gas and abdominal cramps as the fiber is poorly digested and absorbs water in the gut.
- High fructose ingestion from sports drinks, gels and chews can result in abdominal cramps, bloating and diarrhea.
- The osmolality and carbohydrate concentration of some carbohydrate-containing drinks can delay gastric emptying and draw fluid into the gut, potentially contributing to reflux and nausea.

Training the gut

The gastrointestinal tract is crucial for delivering ingested carbohydrate and fluids to the body during exercise. It has been demonstrated that the gastrointestinal system is highly adaptable and that both gastric emptying (the rate at which food and fluids empty from the stomach) and stomach comfort can be 'trained' over time through various methods. Training the gut can indirectly improve performance by effectively absorbing and metabolizing carbohydrates and also reducing any gastrointestinal discomfort experienced by athletes. Figure 4 shows various methods which can be used to train the gut, along with their physiological effects.

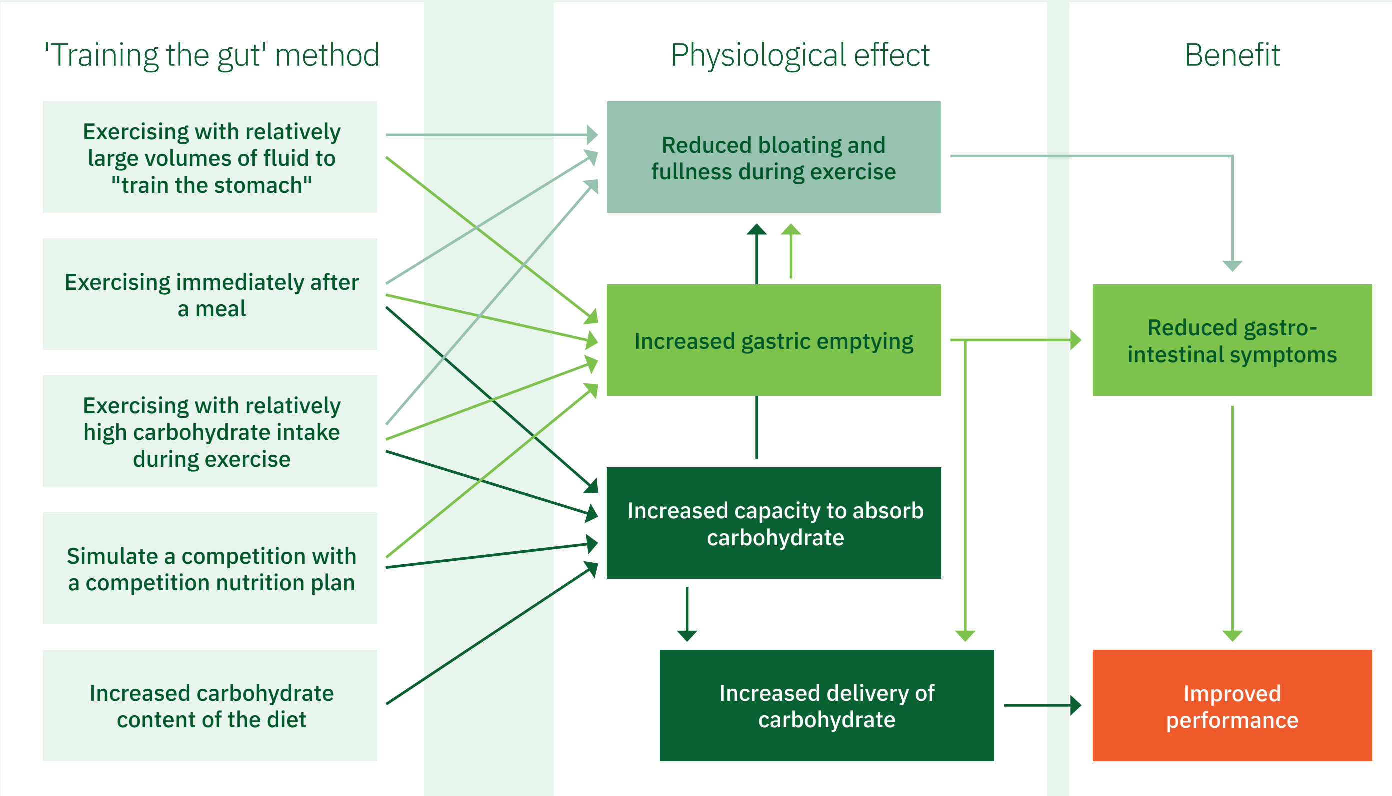


Figure 4: Methods for 'Training the gut'
Adapted from Jeukendrup (2014)

Considerations

Athletes should be encouraged to practice their competition nutrition strategy prior to a competition, especially if the exercise duration is prolonged, so that they can become familiar with higher carbohydrate intakes.

Athletes who have a low consumption of carbohydrate e.g., those following a low-carbohydrate, high fat or ketogenic diet, or those who are reducing daily energy intake to lose weight, will have a reduced capacity to absorb carbohydrates during exercise.

Encourage athletes to regularly practice consuming carbohydrate during exercise, including high carbohydrate intakes during prolonged exercise.

FUELING DURING EXERCISE

Potential benefits of optimal fueling during exercise

- **Increased exercise capacity**
- **Improved performance**
- **Maintain carbohydrate oxidation**
- **Prevent hypoglycemia**

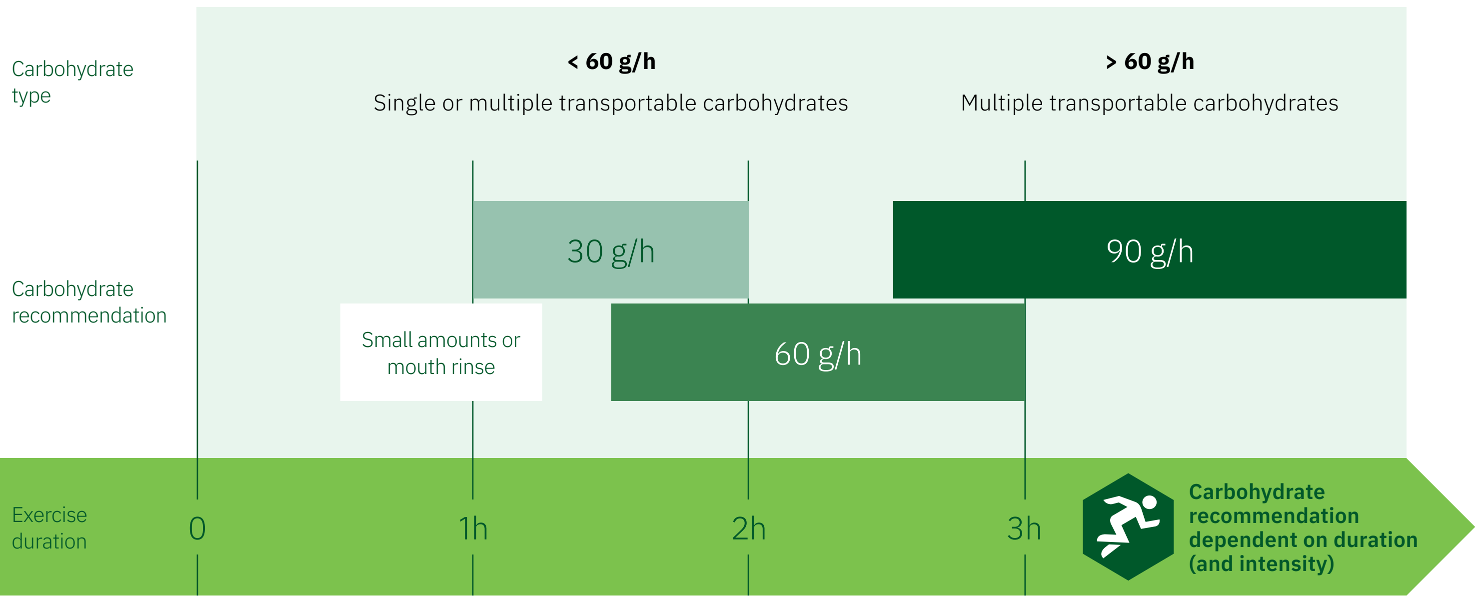
Carbohydrate recommendations for different exercise durations

< 30 minutes
No carbohydrate necessary

30-75 minutes
Small amount of carbohydrate OR carbohydrate mouth rinse

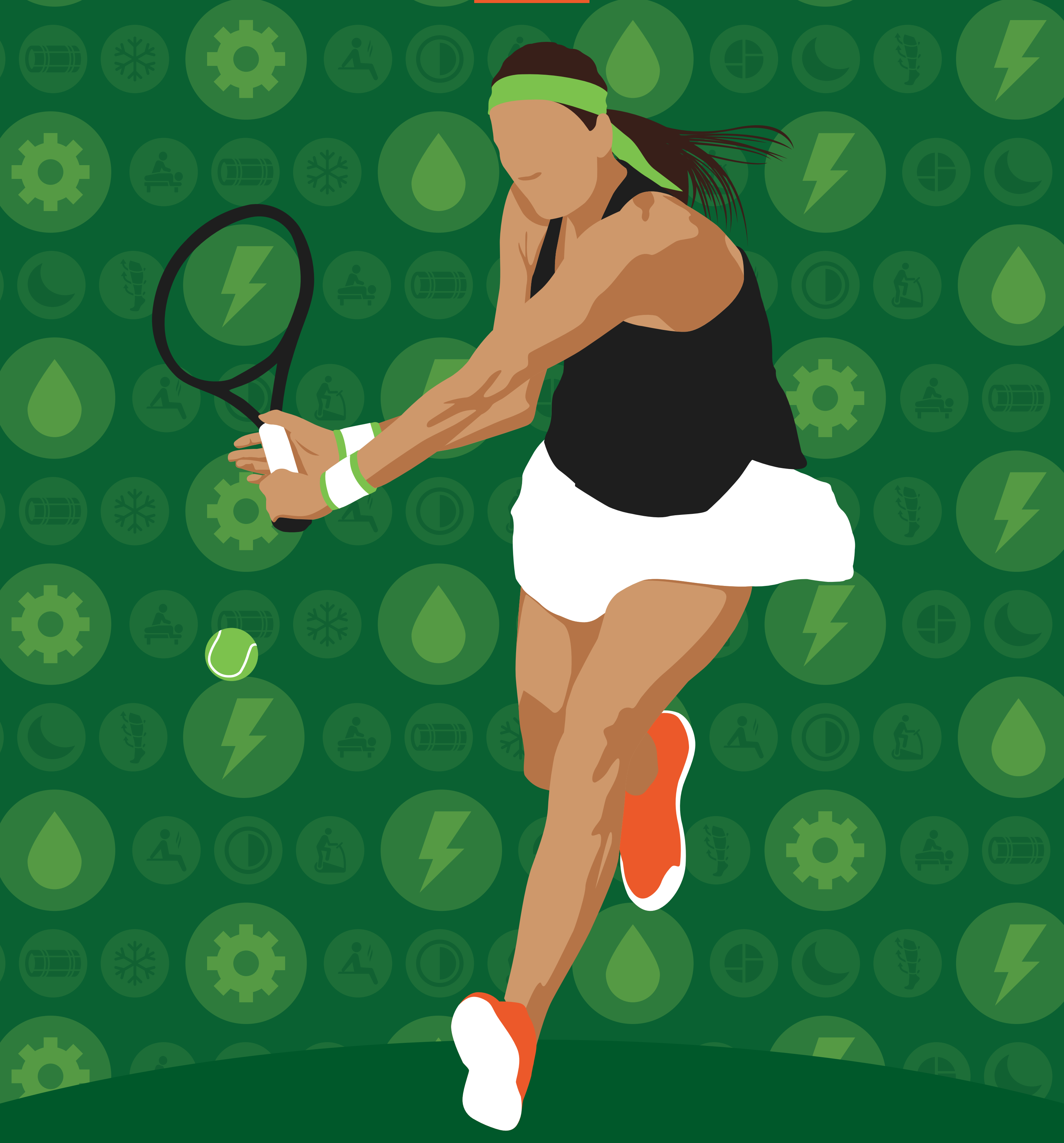
1-2 hours
30-60 grams of carbohydrate per hour

2-3 hours
60-90 grams of carbohydrate per hour



Fuel sources during exercise

- **Sports drinks**
- **Gels**
- **Energy bar**
- **Solid food**
- **Gummies**



Recovery

Introduction

The use of recovery strategies after exercise helps athletes to be ready to perform again during their next bout of exercise. From a nutrition perspective, there are three important recovery factors that should be focused on: refueling energy (glycogen) stores, repairing muscles, and rehydrating the body. These nutrition strategies will complement and maximize the benefits from other recovery modalities such as foam rolling, ice baths, sleep, compression, garments, and massage (it should however be noted that the scientific evidence for each modality varies).

Consistency in recovery after exercise will be beneficial to an athlete's overall health and performance. The information below will explain key nutrition considerations to optimize and speed up recovery after exercise, which is especially important during periods of intense training and competition. It is important to note that there are currently no female-specific guidelines for recovery from exercise. Athletes should be worked with on an individual basis to guide them on how they can optimally meet their recovery needs.

The three key recovery priorities to optimize recovery from a nutrition perspective are: (1) Refuel, (2) Repair and (3) Rehydrate. These can be remembered as the ‘3 R’s’. Each are explained in detail below.

Refuel | **Repair** | **Rehydrate**

Refuel ‣ Carbohydrate

During exercise, especially that of high intensity, the body uses glycogen (carbohydrate) stores for energy. Glycogen stores will decline during exercise and therefore they need to be replenished afterwards. This can be achieved by eating carbohydrate-rich foods and beverages. This will ‘refill’ glycogen stores for when the next bout of exercise begins. It can take up to ~24 hours to fully replenish glycogen stores after exercise, depending on the intensity and duration of the exercise. Higher-intensity and/or longer duration exercise will reduce glycogen stores to a greater extent.

In order to optimize glycogen restoration post-exercise, athletes should ideally consume a snack containing carbohydrate after finishing exercise, within ~30 minutes (Figure 1). Following this, they should aim to eat a meal which contains carbohydrate, within ~2 hours (Figure 3).

If the exercise completed is likely to have depleted glycogen stores, then a more intense strategy is recommended: 1.2 grams of carbohydrate per kg of body mass, per hour, for 4-6 hours. This recommendation is however based on low sample size studies carried out in male athletes.

Some female athletes may find it challenging to consume this amount. If carbohydrate intake is sub-optimal, adding protein to post-exercise drinks or meals can help improve glycogen recovery.

Some situations may require an increase in daily carbohydrate intake following initial refueling. For example:

- During multi-day sporting events
- During a busy period of competition
- When undertaking high-intensity and/or long duration exercise, with multiple exercise sessions during a 24-hour period

Post-exercise high carbohydrate snack ideas

Figure 1

Repair ▸ Protein

Following exercise, muscles need to repair and remodel, which helps the body to adapt to the demands of exercise. To maximize muscle repair and adaptation after exercise (also known as muscle protein synthesis), athletes should aim to consume 20-40 grams of protein at regular intervals i.e., every 3-4 hours.

Following exercise, this can be done by:

- **Having a high protein snack (alongside a high carbohydrate snack) soon afterwards**
- **Having a meal high in protein (and carbohydrate) ~2 hours afterwards (see Figure 3 for examples)**
- **Ensuring high quality protein sources are incorporated into meals and snacks for ~24 hours afterwards**

Athletes may wish to use protein powder during recovery from exercise. As a guide, athletes should aim to use protein powders that contain whey, soy or casein protein, because they are considered a 'complete' source of protein. In addition, protein blends containing a range of plant-based proteins to achieve a full complement of EAA can also be advised.

Examples of 20-40g of protein

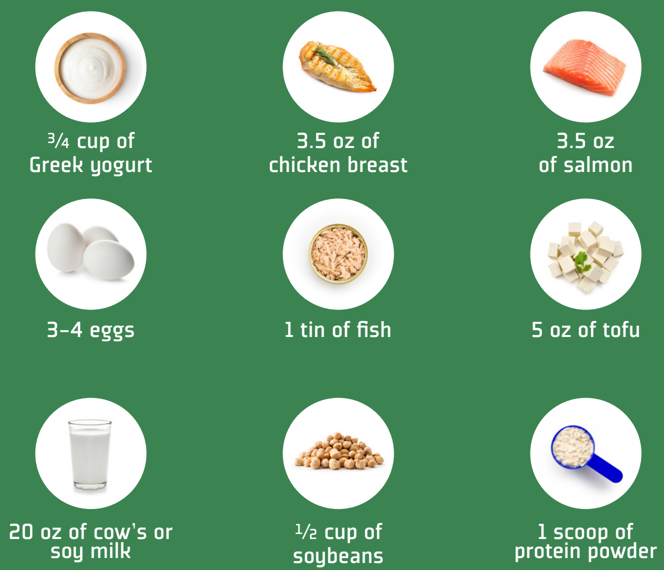


Figure 2

Example recovery meals

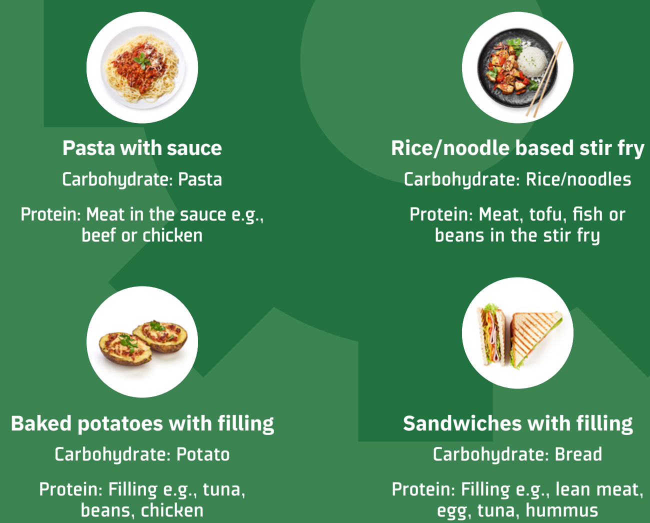


Figure 3

Consuming protein prior to sleeping is beneficial for overnight recovery. Some pre-sleep high protein snack ideas include:

Rehydrate ▸ Fluids

Rehydration is an important part of the recovery process in order to replace fluid lost during exercise. The aim is to completely replace fluid and electrolyte losses prior to the start of the next bout of exercise. Athletes can obtain personalized post-exercise fluid requirements by using the Gx patch, or by using the guidelines set out in 'Hydration'. In brief, athletes should begin to rehydrate immediately after exercise by sipping on fluids such as water, a sports drink or a protein shake. Following this, athletes should continue to sip on fluids to continue to rehydrate.

In most situations, normal eating and drinking practices will replace water and sodium that has been lost. However, if dehydration is severe (>5% of body mass) or if rapid rehydration is needed (<24 hours before next exercise bout), it is recommended for athletes to drink 1.5 L of fluid for each 1 kg of body mass lost.

Practical suggestions

Beverages often provide a convenient option as athletes can sip on them at their own pace if they do not have appetite for food. Suggested items to meet all recovery requirements after exercise are protein shakes or smoothies (both ideally made with milk, see Figure 4). These are both good options because they contain the fluid, protein and carbohydrate to kick start an athlete's recovery all in one go. Dairy and soy milks (including flavoured milks) are also good options to include within a post-exercise recovery beverage for the same reason. If athletes have the resources, they can prepare a smoothie before exercise, or buy a ready to drink beverage, to take with them to ingest straight after exercise. In addition, sports drinks are a good option post-exercise because they contain fluid and electrolytes, as well as carbohydrate, which help athletes to begin rehydrating and refueling.

Recovery smoothies

Mix and match the ingredients below to create a smoothie which contains carbohydrate, protein and fluid - the perfect post-exercise recovery snack!

Protein

- Protein powder
- Milk powder
- Yogurt

Carbohydrate

- Fruits: Banana, apple, mango, pineapple, orange, strawberry, cherries, blueberries
- Honey
- Frozen fruit
- Dried fruits

Fluid base

- Water
- Fruit juices (adds carbohydrate)
- Cow's milk (adds protein)
- Soy milk (adds protein)
- Almond milk
- Oat milk

Figure 4

Considerations

It is important to recognize that it is natural for athletes not to feel hungry after exercise. It is however a barrier to meeting nutrition recommendations to support recovery. If this is an issue, there are strategies that can be used to ensure athletes still recover. After athletes have finished exercise, they can wait 20-30 minutes for the blood to be redistributed from exercising muscles to the gut before starting their recovery food or beverage. They can then begin to sip on fluids, rather than being in a hurry to begin eating solid foods.

The guidelines outlined above are to "optimize" and "speed up" recovery. The need to recover quickly depends on when the athlete is next required to perform. In many circumstances there is plenty of time to refuel, repair and rehydrate in the days prior to the next intense bout of exercise, allowing athletes time to be ready to perform at their best again.

Competition recovery timeline

	Potential general recovery strategies	Nutrition recovery strategies
COMPETITION DAY	**Compression garments** **Sleep**	**Within 30 min afterwards** A snack high in carbohydrate and protein **Within ~2 hours afterwards** A meal high in carbohydrate and protein **Rehydrate post-competition with fluids** Milk based drinks, a protein shake or a sports drink are good options
COMPETITION DAY +1	**Foam rolling and stretching** **Massage/physio treatment** **Active/gym recovery** **Bath/jacuzzi/sauna/contrast therapy**	**Ensure meals contain sufficient and high quality carbohydrate and protein sources** **Continue to rehydrate with fluids and monitor hydration status**

Refuel

- Carbohydrate snack within 30 mins
- Carbohydrate-rich meal within 2 hours
- Adjust daily carbohydrate intake according to duration and intensity of exercise completed
- If carbohydrate intake is sub-optimal, adding protein to meals/ snacks can help improve glycogen recovery

Repair

- Protein source (20-30g) after exercise
- Ensure high protein foods are included in meals for 24 hours afterwards
- Pre-sleep protein

Rehydrate

- Sip on fluids
- Ideally consume 125-150% of body mass losses
- Combine fluids with meals / food

Post Exercise

Shake, milk or smoothie

Competition Day

Competition Day + 1

Supported by additional strategies

Energy Availability

Introduction

A fundamental nutrition consideration for athletes is ensuring sufficient energy for the exercise that they are undertaking. Providing the body with an adequate amount of energy is beneficial to an athlete's health and performance. On the other hand, if energy needs are consistently not met, this may have a negative impact on health and performance. The information below will explain the importance of energy, the concepts of energy balance and energy availability, as well as the consequences of inadequate energy availability. Finally, practical solutions will be shared to help female athletes consistently meet their energy needs.

Energy balance

Energy balance refers to the balance between the amount of energy (kilocalories, kcal) consumed through food and drink (i.e., energy intake) and the amount of energy expended by the body (i.e., energy expenditure). Depending on the difference between energy intake and energy expenditure, an athlete can be in an 'energy deficit' or an 'energy surplus' (Figure 1).

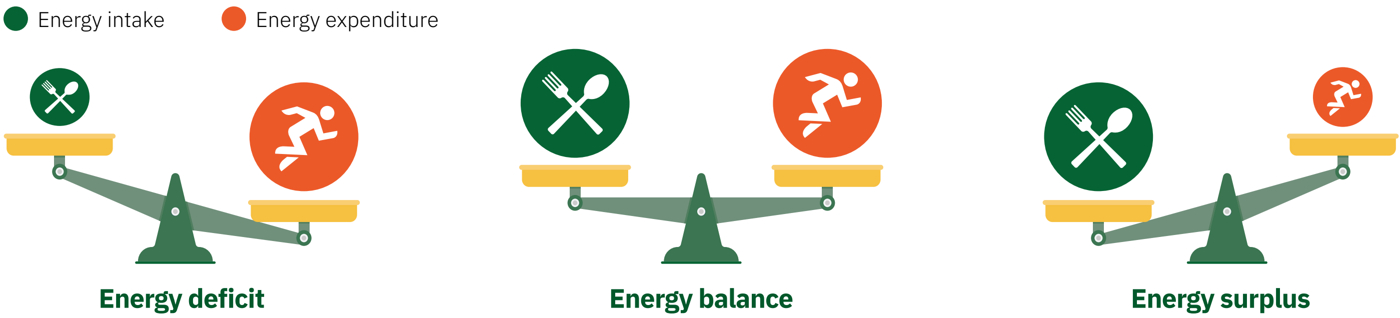


Figure 1: Energy deficit, energy balance and energy surplus

Daily energy requirements

There are three main processes which contribute to the body's total daily energy expenditure (TEE) which are basal metabolic rate, thermic effect of food, and thermic effect of activity (Figure 2). Daily energy intake requirements to ensure energy balance vary from athlete to athlete, mainly dependent on the duration and intensity of exercise.

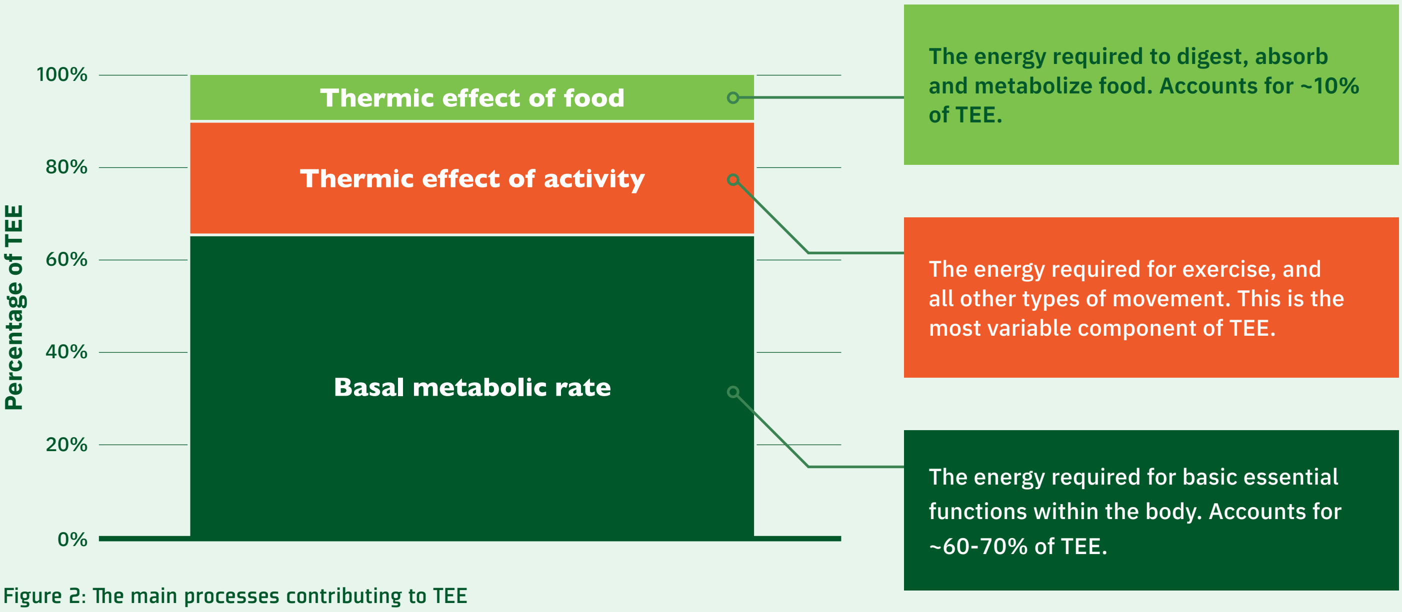


Figure 2: The main processes contributing to TEE
TEE = Total Energy Expenditure

Energy availability

Energy availability refers to the amount of energy available for bodily physiological and homeostatic processes to function properly, after accounting for the energy expended through exercise (i.e., exercise energy expenditure). Energy availability is expressed relative to fat free mass, the body's most metabolically active tissue. The calculation for energy availability is as follows:

$$\text{Energy availability (kcal/kg FFM/day)} = \frac{\text{Energy Intake (kcal)} - \text{Exercise Energy Expenditure (kcal)}}{\text{Fat Free Mass (kg)}}$$

The body requires enough energy available for important physiological functions and systems, such as:

- **Immune system**
- **Reproductive system**
- **Hematological function**
- **Neurocognitive function**
- **Cardiovascular function**

Low energy availability (LEA)

Many athletes expend large amounts of energy on a daily basis through undertaking intense training loads. It is important that athletes consistently meet their energy needs to ensure that their body has sufficient energy available to carry out fundamental physiological processes that are important for health, as well as to support their exercise demands. If an athlete's body consistently does not have enough energy left after exercise to support fundamental physiological functions, this can result in what is known as 'low energy availability' (LEA). LEA is the underlying cause of the conditions known as Relative Energy Deficiency in Sport (REDs) and the Female Athlete Triad. For more about these conditions, see the reference and resources list.

According to the IOC 2023 consensus statement (Mountjoy et al., 2023), LEA occurs as a continuum between:

1 Adaptable LEA

Exposure to reduced energy availability. Associated with benign effects which are mild and easily reversible, typically having little to no impact on long-term health, well-being or performance.

2 Problematic LEA

Exposure to low energy availability. Associated with greater disruption to body systems, which can potentially cause long-term impairments to health and performance.

Causes of LEA

The fundamental causes of LEA are inadequate energy intake and/or failure to match energy intake to training regimes. This is demonstrated in mathematical terms in the table below.

Table 1: Theoretical calculations for adequate EA and LEA

	Exercise Energy Expenditure (kcal/day)	Energy Intake (kcal/day)	Energy Availability (kcal/kg FFM/day)
Adequate EA	500	2700	45*
LEA through inadequate energy intake	500	1900 ▼	29 ▼
LEA through failure to match energy intake to high training load	1300 ▲	2700	29 ▼
LEA through a combination of inadequate energy intake and failure to match energy intake to high training load	1000 ▲	2200 ▼	24 ▼

Example: 60 kg (132 lb); 49 kg (108 lb) FFM

*In this example, 45 kcal/kg FFM/day has been used to demonstrate adequate EA, however please note that thresholds for EA are debated.

Factors contributing to the development of LEA

There are a number of factors which can contribute to the development of LEA, related to either inadequate energy intake or failure to match energy intake to high training load (Figure 3). Through education and awareness, many of these barriers can be addressed to minimize the likelihood of an athlete inadvertently experiencing low energy availability.

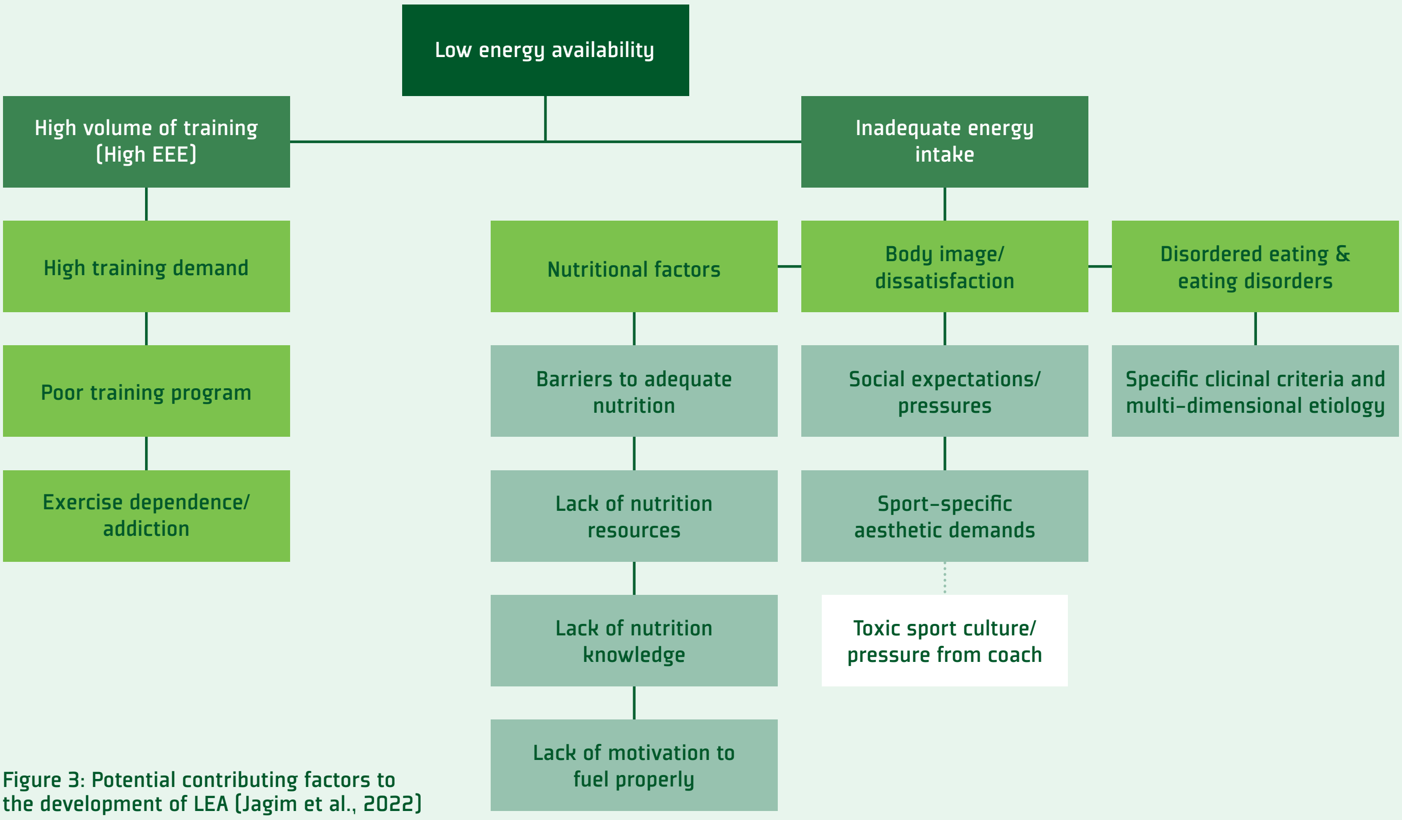


Figure 3: Potential contributing factors to the development of LEA (Jagim et al., 2022)

Assessing LEA

It is challenging for practitioners to accurately measure all components of energy availability (i.e., energy intake, exercise energy expenditure and fat free mass), in particular energy intake and exercise energy expenditure. In turn, this makes it difficult to identify LEA, particularly in the field. Alternatively, there are several screening tools which have been produced to assess LEA and its associated outcomes. These include:

Low Energy Availability in Females Questionnaire (LEAF-Q)	RED-S Specific Screening Tool (RST)	Eating Disorder Examination Questionnaire (EDE-Q)
Exercise Addiction Inventory (EAI)	Exercise Dependence Scale (EDS)	IOC Relative Energy Deficiency in Sport Clinical Assessment Tool-2 (IOC REDs CAT2)

Signs, risk factors and consequences of LEA

It is important for coaches, support staff and athletes to be aware of potential signs and risk factors of LEA in female athletes (Figure 4). It is important to note that the signs and risk factors shown below are not an exhaustive list. In addition, an athlete does not need to show all of these symptoms to be experiencing LEA.

Menstrual irregularities or complete loss of menstrual cycle	Chronic dietary restriction and/or extreme dieting	History of bone stress injuries
Low bone mineral density	Poor recovery between training sessions	Clinically diagnosed depression and/or anxiety
Lack of ovulation	Urinary incontinence	Gastrointestinal symptoms at rest/during exercise
Reduced or low resting metabolic rate	Sleep disturbances	Increased stress or anxiety
Exercise dependence/ addiction	Difficulty concentrating	Perfectionist tendencies
Frequent injuries	Training inconsistencies	Constant fatigue

Figure 4: Potential indictors of LEA in female athletes

Health and performance impacts of LEA

The REDs Health/Performance conceptual models (Mountjoy et al., 2023) outline the range of impacts that LEA can cause. The outcomes shown will occur over different time periods, and with differing severities. In addition, the outcomes experienced may differ between individuals. Please also note that the impacts captured within the conceptual models can occur due to etiologies other than problematic LEA.

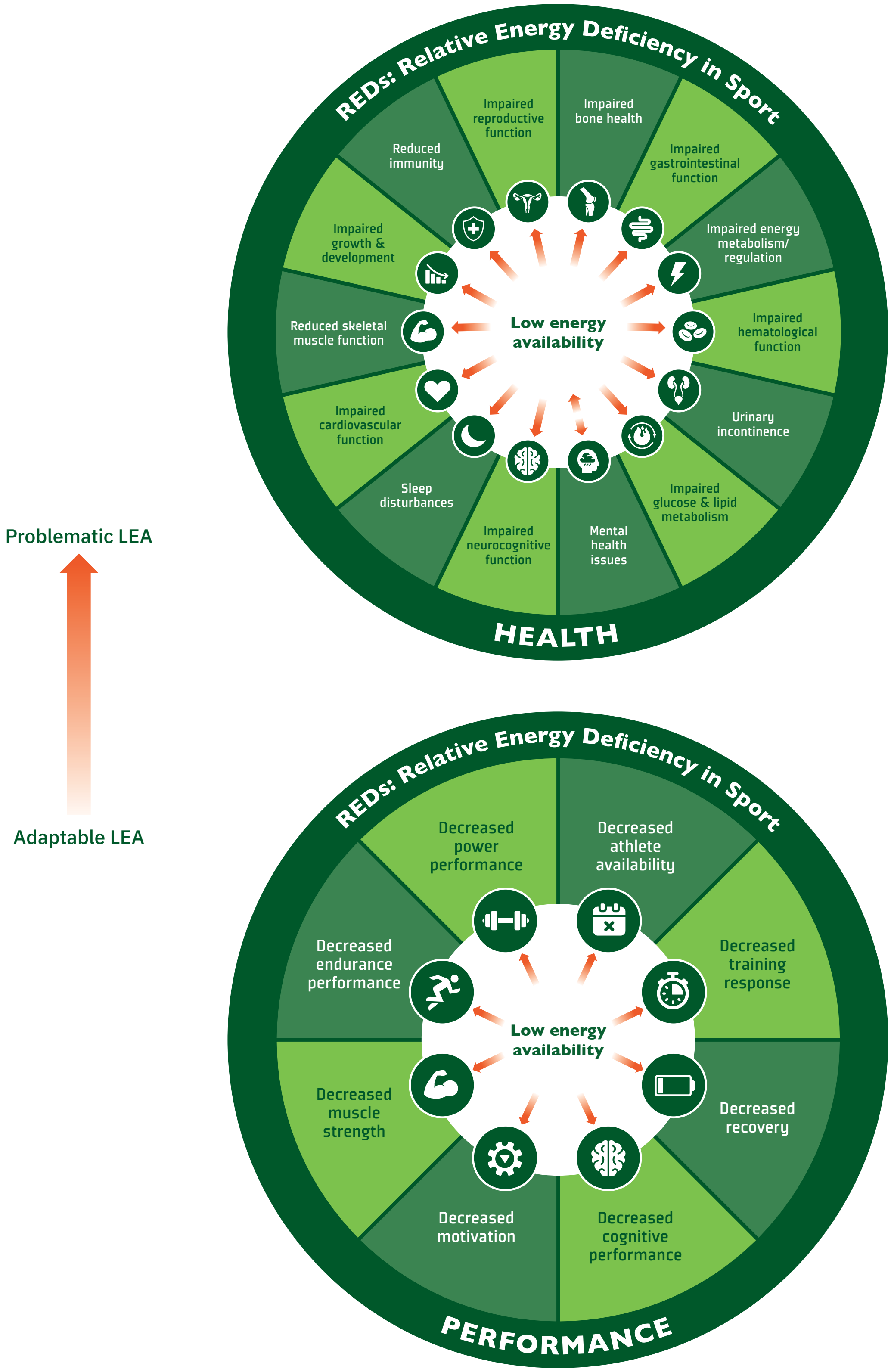


Figure 5: REDs Health and Performance conceptual models (Mountjoy et al., 2023)

Prevalence of LEA

It is suggested that LEA is more likely to occur in certain types of sports:

Aesthetic sports (e.g., gymnastics) and weight sensitive sports (e.g., wrestling, jockeys): potentially due to eating disorders and/or disordered eating* being more prevalent in these sports, which impacts energy intake, thus increasing the risk for LEA. In weight sensitive sports, adaptable LEA may be more common during periods of weight loss in preparation for competition.

Endurance based sports (e.g., running, cycling): potentially due to high volumes of training resulting in increased exercise energy expenditure, which in turn increases the risk for LEA.

*It should be noted that LEA can occur both with and without an eating disorder/disordered eating

Estimated prevalence of LEA in female athletes according to research:

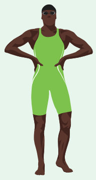
Ballet dancing
Prevalence of LEA: 22%
Mean age: 18
Sample size: 20
Civil et al. (2018)

Soccer
Prevalence of LEA: 23%
Mean age: 24
Sample size: 13
Moss et al. (2021)

Endurance running
Prevalence of LEA: 31%
Mean age: 26
Sample size: 35
Heikura et al. (2018)

Basketball
Prevalence of LEA: 40%
Mean age: 20
Sample size: 15
Çetiner-Okşin et al. (2023)

Rowing
Prevalence of LEA: 64%
Mean age: 25
Sample size: 25
Scheffer et al. (2023)



Swimming
Prevalence of LEA: 40%
Mean age: 20
Sample size: 15
Klein et al. (2023)

Volleyball
Prevalence of LEA: 20%
Mean age: 21
Sample size: 10
Woodruff et al. (2013)

Rugby union
Prevalence of LEA: 52%
Mean age: 21
Sample size: 15
Traversa et al. (2022)

Gymnastics
Prevalence of LEA: 100%
Mean age: 16
Sample size: 13
Villa et al. (2021)

Lacrosse
Prevalence of LEA: 50-75%
Mean age: 20
Sample size: 20
Zabriskie et al. (2019)

Synchronized swimming
Prevalence of LEA: 100%
Mean age: 20
Sample size: 11
Schaal et al. (2017)

Softball
Prevalence of LEA: 100%
Mean age: 20
Sample size: 17
Torres-McGehee et al. (2021)

The value of < 30 kcal/kg FFM/day, which is commonly utilized in research, has been used as a cut-off value for LEA. It should be noted that it is difficult to determine the exact prevalence of LEA due to variability in the methods used to assess energy availability. The prevalence of LEA may also be dependent on other contextual factors such as level of competition, age, phase of the season, etc.

LEA: Females vs. males

Both females and males can experience LEA, however research suggests that the prevalence of LEA is higher in female athletes vs. male athletes. Research into the endocrine and bone metabolism responses to LEA suggest that **females are less resilient to the effects of LEA in comparison to males.** One explanation for this is that the energetic cost of maintaining the reproductive system, as well as gestation, are significantly higher for females in comparison to males. This means that females may be more sensitive to reductions in energy availability, due to the body preserving energy to ensure successful gestation can still occur during periods of LEA.

Practical tips to prevent the development of LEA

- Ensure an athlete's diet provides enough energy to support the demands of both their training and daily life
- Teach athletes flexible eating behaviours: encourage them to acknowledge the importance of a nutrient-dense diet while not putting labels such as 'good' or 'bad' on single food groups or macronutrients
- Make athletes, coaches and support staff aware of the signs and symptoms of LEA
- Create a safe environment for athletes in communal eating spaces
- If there is an increase in an athlete's training volume and/or intensity, ensure that energy intake increases accordingly
- Encourage athletes to be cautious of misinformation and trends on social media
- Consider whether body composition management is essential, and if so, ensure it is carried out by a qualified professional
- Report toxic training environments where athletes are shamed for the size and/or shape of their bodies

ENERGY AVAILABILITY

Energy availability is "the amount of energy available to the body for physiologic and homeostatic processes, after accounting for energy expended through exercise".

Research suggests that the prevalence of low energy availability (LEA) is higher in female athletes than male athletes.

Adequate energy is important for physiological functions and systems

- Immune system
- Reproductive system
- Hematological function
- Neurocognitive function
- Cardiovascular function

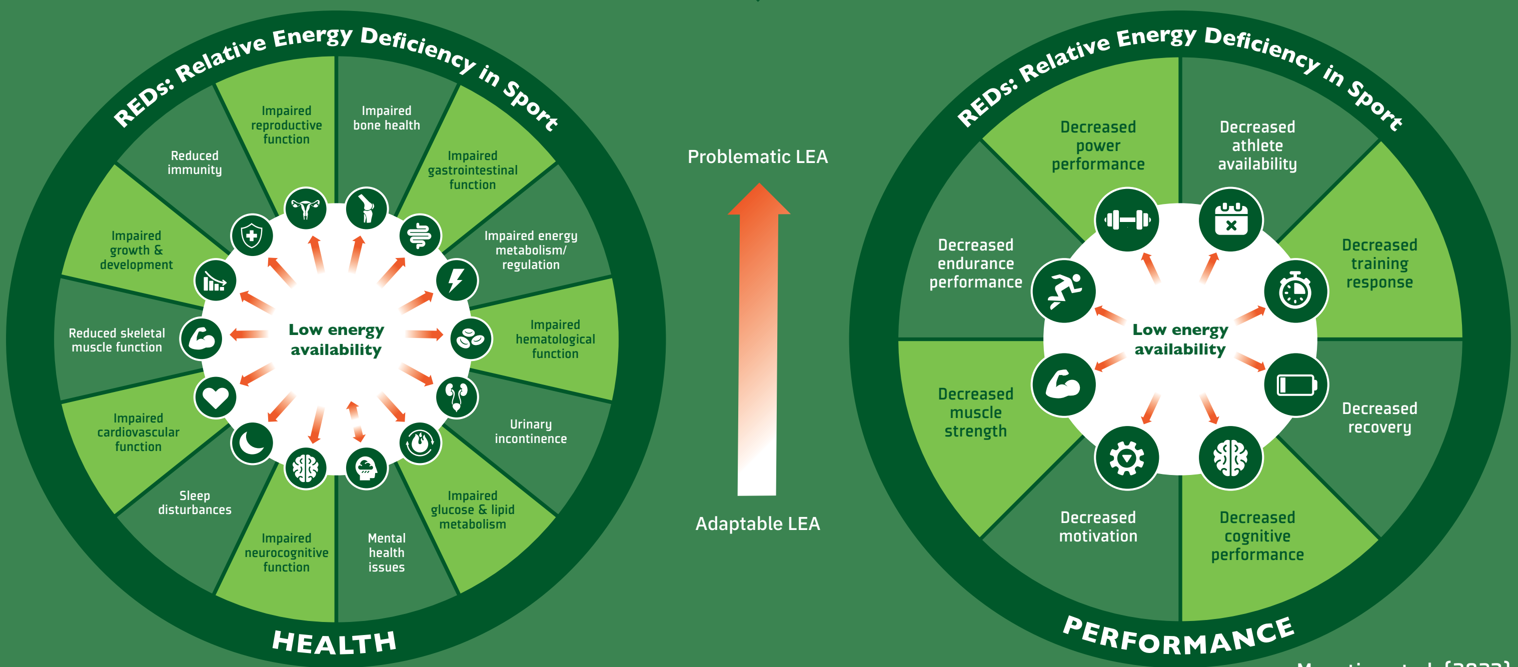
Potential contributing factors to the development of low energy availability

Low energy availability

- **High volume of training (High EEE)**
  - High training demand
  - Poor training program
  - Exercise dependence/ addiction
- **Inadequate energy intake**
  - Nutritional factors
    - Barriers to adequate nutrition
    - Lack of nutrition resources
    - Lack of nutrition knowledge
    - Lack of motivation to fuel properly
  - Body image/ dissatisfaction
    - Social expectations/ pressures
    - Sport-specific aesthetic demands
    - Toxic sport culture/ pressure from coach
  - Disordered eating & eating disorders
    - Specific clicinal criteria and multi-dimensional etiology

Jagim et al. (2022)

Potential impacts of low energy availability

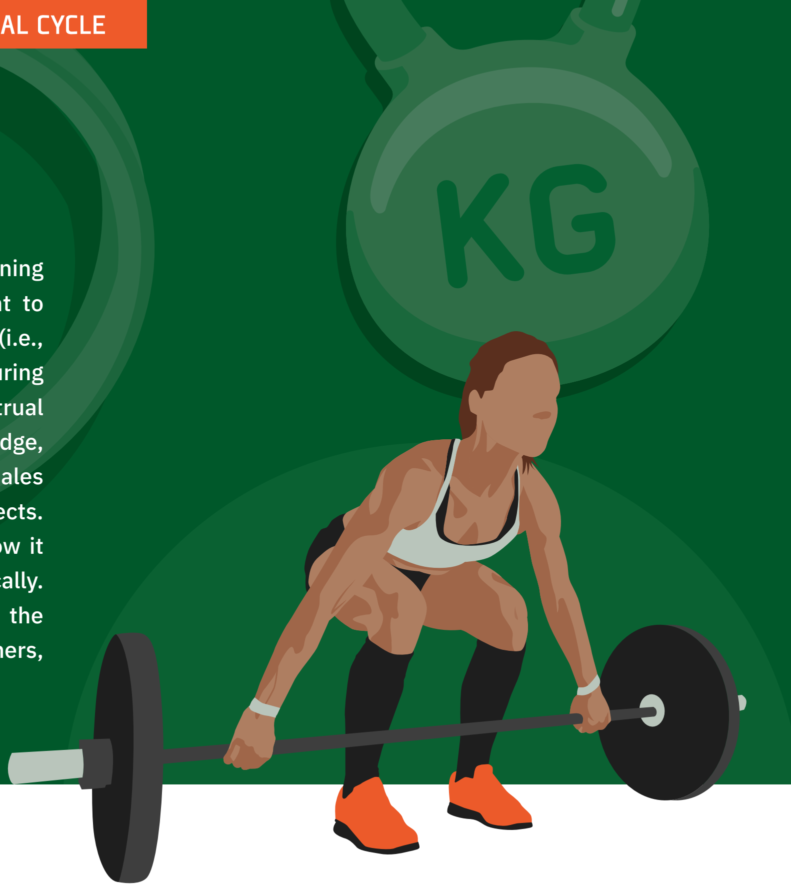


Mountjoy et al. (2023)

Menstrual Cycle

Introduction

The word 'menstrual' comes from the Latin word 'mensis' – meaning 'month'. When talking about the menstrual cycle, it is important to note that this is not just the days when an athlete is menstruating (i.e., bleeding), but it is a whole cycle (typically one month in duration) during which there are fluctuations in female sex hormones. The menstrual cycle is a biopsychosocial phenomenon meaning that the knowledge, attitudes and beliefs of the menstrual cycle will influence how females experience and interpret the biological changes, symptoms and effects. The following information will discuss the menstrual cycle and how it may (or may not) affect female athletes both emotionally and physically. We hope this information will encourage comfort in discussing the menstrual cycle between female athletes, coaches, practitioners, medical staff, and others.



What is the menstrual cycle?

The menstrual cycle is the time between the first day of bleeding (known as a period, or menstruation) and the day before the next period. On average, the duration of a typical menstrual cycle is 28 days, however it differs between individuals, and can range from 21 to 35 days. Cycle duration can also vary from month to month within the same individual. Each period has an average length of 2-7 days.

Females have approximately 480 periods during their lifetime

Primarily, the menstrual cycle is controlled by the brain which initiates fluctuations of female sex hormones throughout the cycle. There are changes in two main female sex hormones, known as estrogen and progesterone. In brief, estrogen repairs, thickens and maintains the lining of the uterus, and progesterone maintains the lining of the uterus during the latter part of the menstrual cycle. Two other hormones which play a key role in the menstrual cycle are the follicle stimulating hormone (FSH) and luteinizing hormone (LH). FSH stimulates the growth and development of follicles in the ovary, which in turn produce estrogen. LH surges in the middle of a menstrual cycle, and triggers ovulation.

Ovulation is when an egg is released from the ovaries. It usually occurs around the middle of the menstrual cycle, however, it is difficult to know the exact day due to varying cycle lengths. The egg normally lives for 12-24 hours after release, and if not fertilised in this time it will die. Following ovulation, LH aids the production of progesterone.

The menstrual cycle can be split into three different phases

1. **Follicular phase** (beginning of the cycle)
2. **Ovulatory phase** (middle of the cycle)
3. **Luteal phase** (latter part of the cycle)

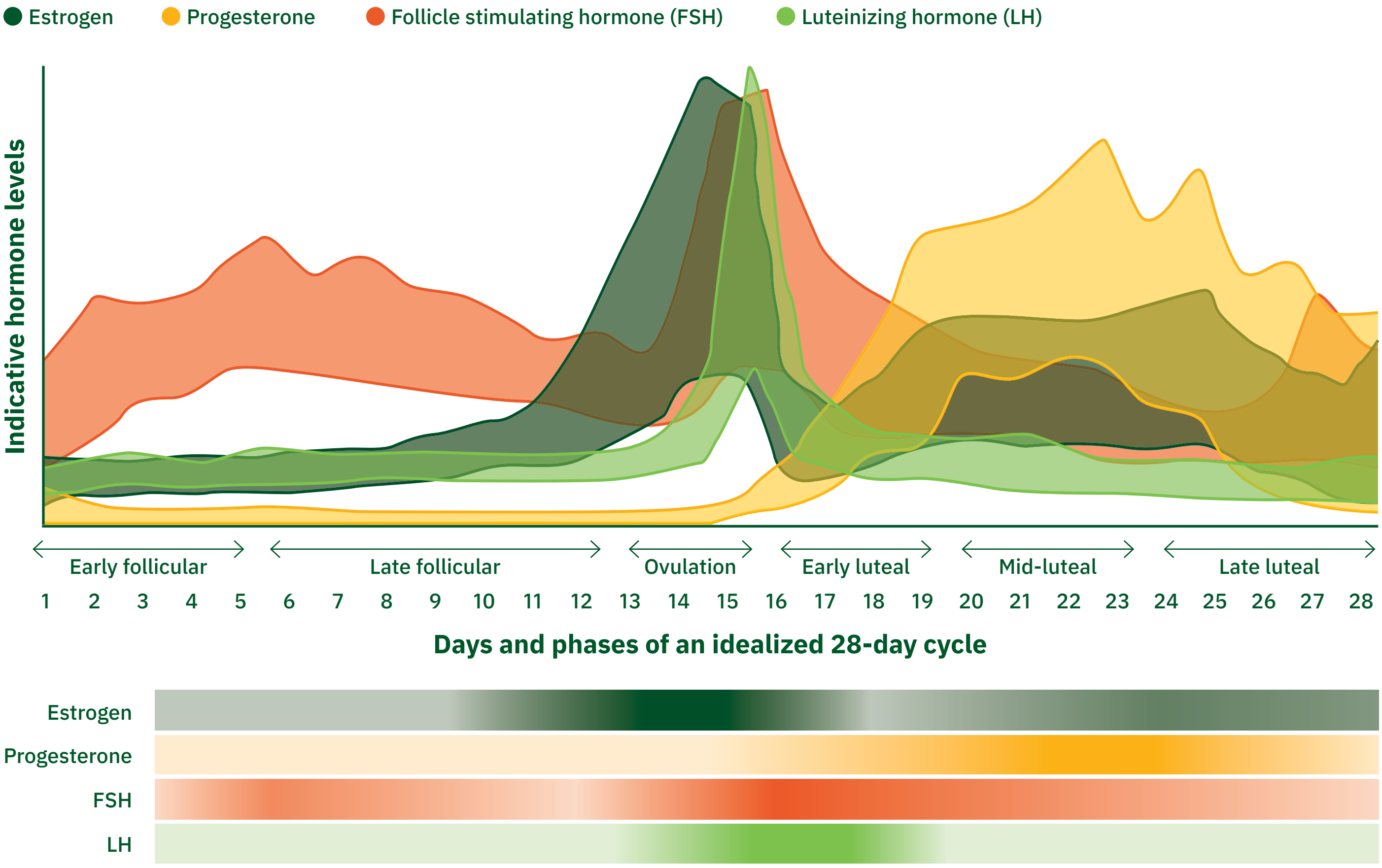


Figure 1: Fluctuations in female sex-specific hormones during the main phases of the menstrual cycle (adapted from D'Souza et al. (2023))

Important information if working with youth athletes

The average age of first menstruation, which has been on the decline, is around 12–13 years. When females first start their menstrual cycle, their cycle length can be irregular, as the body is getting used to the changes in hormones.

It is recommended that female athletes should seek professional medical advice if:

- **They haven't started their period by the age of 16**
- **Their periods stop for several months**
- **They experience extremely severe symptoms**

Menstrual cycle symptoms

Data reported from elite female athletes has found that ~77% experience negative symptoms during their menstrual cycle. The type and severity of menstrual cycle symptoms varies between individuals. In some individuals, symptoms can be experienced throughout the entire menstrual cycle, but data has revealed that the majority (82%) of symptoms are experienced in the first 1-2 days of menstruation. It is also common for symptoms to be present in the week prior to menstruation, this is referred to as pre-menstrual syndrome (often abbreviated as 'PMS') and can cause physical and emotional changes. Some of the most reported physical and emotional symptoms in female athletes are stomach cramps, back pain, and mood swings. It is important to note that symptom type and severity can vary within the same individual from cycle to cycle.

Ovulatory phase*	Days just before and during period*
Breast tenderness	**Changes in appetite**
Bloating	**Mood swings**
Cramps	**Irritability**
Slight rise in body temperature	**Fatigue**
Increased cervical mucus	**Bloating**
Pelvic or abdominal pain	**Breast tenderness**
	Headaches
	Cramps
	Spotty skin
	Lower back pain

*Not all symptoms apply to all individuals

Figure 2: Potential symptoms experienced during different menstrual cycle phases

Menstrual cycle disruption

In non-pregnant, pre-menopausal women, the menstrual cycle may stop or become irregular for a number of reasons including increased stress, or hormonal contraceptive use. Menstrual cycle disruption may also occur if a female athlete is experiencing low energy availability (see 'Energy Availability' for more information). This occurs when an athlete's body consistently does not have enough energy left after exercise energy expenditure has been accounted for to support fundamental physiological functions, including the menstrual cycle. If athletes are in a state of low energy availability for a prolonged period of time, menstrual cycle disruptions such as oligomenorrhea and amenorrhea can occur:

Oligomenorrhea	Amenorrhea
fewer than 6-8 periods per year	**complete loss of periods**

It is important to note that disruption to the menstrual cycle is only detectable in females that have a 'natural' menstrual cycle, and not in those that use hormonal contraceptives. Therefore, advice from a qualified professional is important if athletes are experiencing menstrual cycle disruptions (Figure 3).

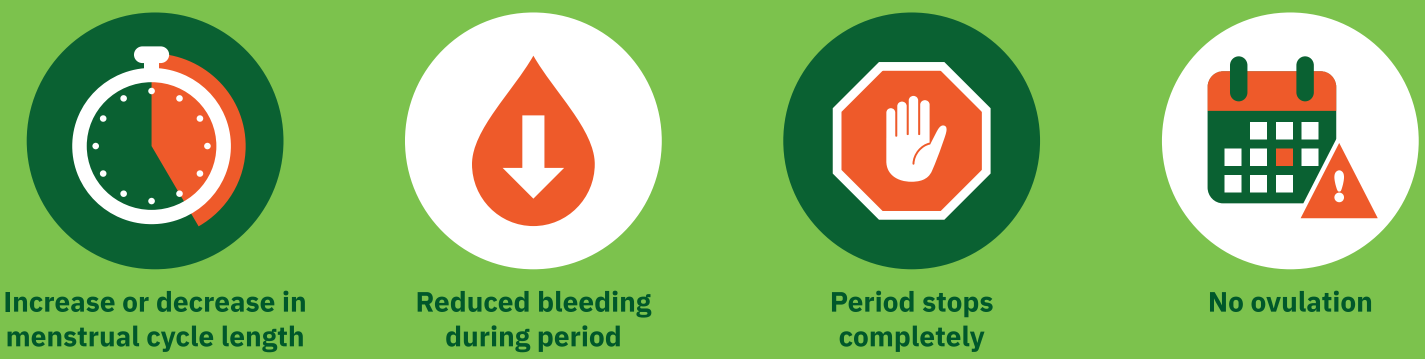
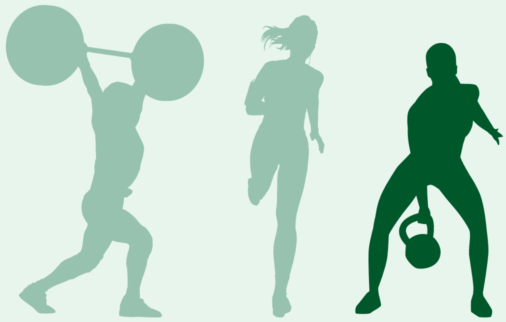


Figure 3: Potential menstrual cycle disruptions

Heavy menstrual bleeding

Heavy menstrual bleeding (HMB), which is also known as menorrhagia, is when menstrual cycle bleeding is particularly heavy or prolonged. Athletes that experience HMB may:

Pass large blood clots	Need to use two types of sanitary products at once	Bleed through clothes
Need to change sanitary products frequently	Have periods that last > 7 days	Often feel tired



Research suggests that around one in three exercising females experience HMB

HMB can reduce well-being and confidence, and create concern in clothing choices (a factor that is often outside of an athletes control). In addition, those that experience HMB are more likely to suffer from an iron deficiency. Research shows that female athletes with HMB are more likely to perceive that their period negatively impacts their training and performance.

Athletes with HMB often do not feel comfortable discussing this with support staff, coaches or medical staff. However, it is important to create an environment that facilitates open conversations about this topic so that athletes can sought help, which in turn will help manage the impact of HMB on well-being and performance.

Nutrition and the menstrual cycle

There is currently no evidence to suggest that diet should be altered depending on the phase of the menstrual cycle. Instead, athletes should focus on optimizing their daily nutrition as well as optimizing nutrition before, during, and after exercise. General dietary considerations in relation to the menstrual cycle are displayed in Figure 4.

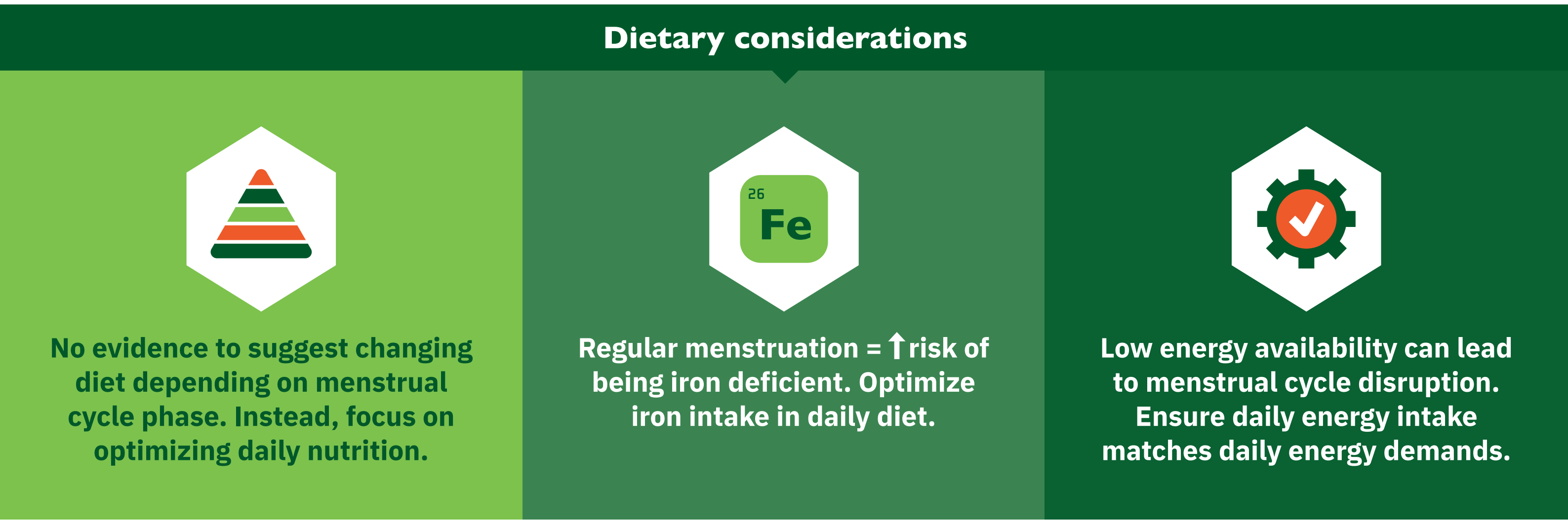


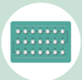
Figure 4: Dietary related factors that may want to be considered

Hormonal contraceptives

Contraception (birth control) comes in a range of preparations, brands, and delivery methods (Figure 5). This section will cover hormonal contraceptives (HC), as opposed to non-hormonal, meaning that they contain artificial hormones, typically estrogen and progestin (the synthetic form of progesterone). A study including 430 elite female athletes found that ~70% had reported using hormonal contraception at some point. No study to date has reported reasons why athletes use hormonal contraception, however potential reasons may be to prevent pregnancy, to alter menstrual cycle around competition, or to prevent negative side effects of the menstrual cycle. A qualified professional should be involved if an athlete wishes to use, or terminate use, of HC.

One of the most popular contraceptives is an oral contraceptive pill (combined pill) taken on a 28-day cycle, whereby an 'active' pill is taken for 21 days, followed by an 'inactive' pill (or no pill) for 7 days, during which a bleed occurs. It is important to note that the bleeding experienced during this time is not natural menstruation, it is a 'withdrawal bleed' which is a result of the levels of the artificial hormones temporarily decreasing. If the 'inactive' pills are skipped and 'active' pills are continuously taken in their place, then bleeding does not occur.

Types of hormonal contraception



Combined pill
Contains artificial estrogen and progestin. Active pill taken for 21 days, followed by an inactive pill for 7 days.

Progestin only pill (POP)
Contains progestin, which thickens mucus in the cervix to stop sperm reaching an egg. One pill taken every day.

Contraceptive patch
Small sticky patch which lasts ~1 week which releases artificial estrogen and progestin.

Vaginal ring
Small plastic ring placed inside the vagina which releases a continuous dose of artificial estrogen and progestin.

Implant
Small, flexible plastic rod placed under the skin in the upper arm which releases progestin.

Injection or "shot"
Injection which releases progestin into the bloodstream.

Intrauterine device (IUD)
Small, T-shaped plastic device placed into the uterus which releases progestin.

Figure 5: Different types of hormonal contraceptions

Hormonal profile of combined oral contraceptive

HC reduce the amount of natural occurring estrogen and progesterone, because they provide artificial hormones into the body. This results in a different hormonal profile to a 'natural' menstrual cycle (Figure 6 is related specifically to the combined oral contraceptive).

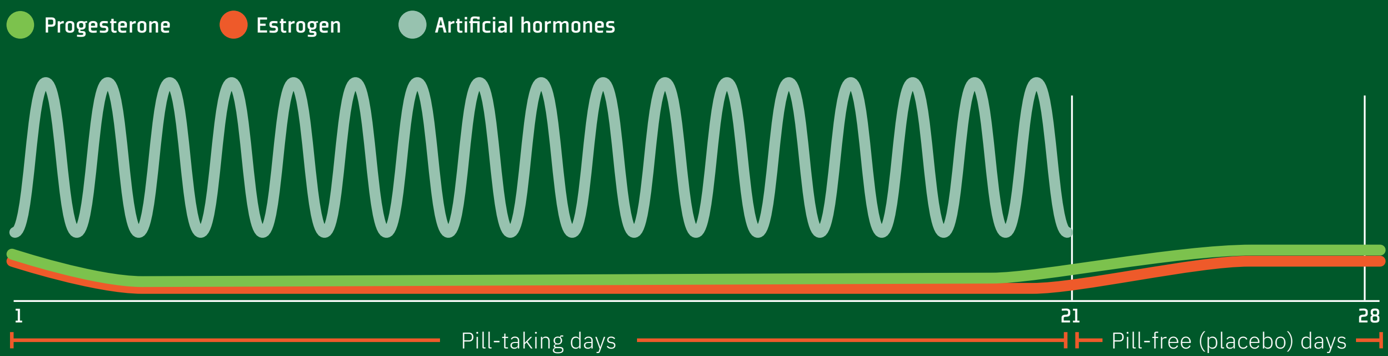


Figure 6: Hormonal profile when using the combined oral contraceptive

Impact of menstrual cycle and hormonal contraceptives on exercise performance

The menstrual cycle is a biopsychosocial phenomenon meaning that the knowledge, attitudes and beliefs of the menstrual cycle will influence how females experience and interpret the biological changes, symptoms, and effects. Feelings and symptoms associated with the menstrual cycle can cause increased anxiety and distraction for athletes.

Research has investigated whether menstrual cycle phase, and therefore the change in hormone levels, has an impact on exercise performance. However, there is currently no strong evidence to suggest that exercise performance is impacted during different phases of the menstrual cycle. Instead, it could be recommended to assess individual performance, as well as measures of energy and well-being, across different phases of the menstrual cycle to assess repeated associations between menstrual cycle phase and performance indices.

Research has also investigated if HC have an affect on exercise performance. There is some evidence to suggest that HC might result in slightly inferior exercise performance on average when compared to natural menstruation. However, only a very small difference in performance outcomes have been observed, and there is not enough evidence to advise athletes not to use HC.

Menstrual cycle tracking

It might be of interest for athletes to track their menstrual cycle. It can help to:

Notice any changes in menstrual cycle e.g., in length or amount of bleeding

Empower athletes to become more in tune with menstrual cycle related symptoms

Better understand the connection between menstrual cycle and other factors e.g., sleep, activity, energy, performance, recovery, mood, etc

If the athlete feels comfortable, encourage them to share this information as it may help to inform their training. For instance, if they consistently struggle to recover from high-intensity sessions during a certain phase of their menstrual cycle, training or recovery time could be adapted accordingly. There are several ways that athletes can track their menstrual cycle including using phone based apps, using a diary/calendar, or simply by writing it down. It is important to note that athletes should track for their whole menstrual cycle, and not just the days that they are bleeding.

As a minimum it is recommended to keep note of:

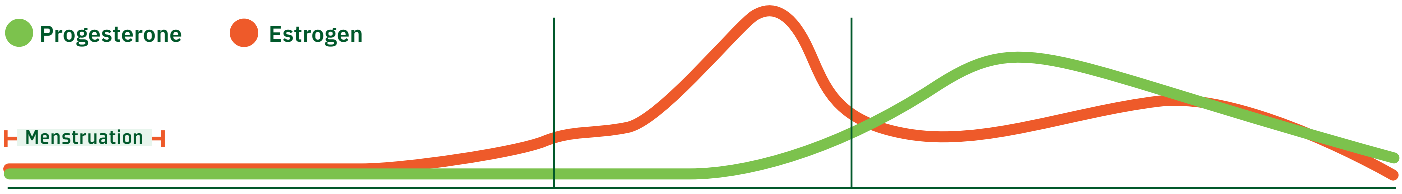
- **Days of bleeding**
- **Bleeding amount**
- **Symptoms**
- **Response to exercise**

Practical advice to support menstrual health and well-being in athletes

- Encourage athletes to speak up if they are experiencing concerns about menstruation.
- The menstrual cycle has historically been perceived as a taboo subject, normalizing the topic will empower athletes to talk to their support team if menstrual cycle issues arise.
- As menstruation can cause symptoms that may impact an athlete's output, encourage athletes to listen to their bodies and get extra rest, hydration, and nutrition as and when required.
- If athletes experience symptoms which impact their ability to exercise during menstruation, then this can present a time to focus on cross training, slower paced endurance exercise, and strength training.
- Assure athletes at the start of the season that they will not be penalized for poor practices or competition performance that may be as a result of their menstrual cycle.
- Ensure that locker room / changing facilities / bathrooms are accessible and always stocked with menstrual products.
- Understand the insecurities that female athletes may have around wearing white clothing (i.e., shorts, pants, leotards, etc).

MENSTRUAL CYCLE

Important for health	Supports performance



Follicular phase
Estrogen levels: Low
Progesterone levels: Low

Ovulatory phase
Estrogen levels: High
Progesterone levels: Low

Luteal phase
Estrogen levels: High
Progesterone levels: High

TRACKING

- Helps to notice changes in menstrual cycle e.g., length or amount of bleeding
- Empowers athletes to become more in tune with symptoms
- Better understand the connection between menstrual cycle and other factors

Track:

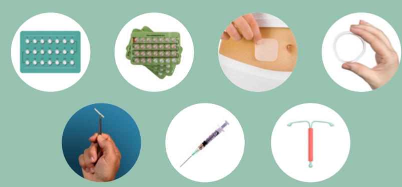
- Days of bleeding
- Bleeding amount
- Symptoms
- Response to exercise

HORMONAL CONTRACEPTIVES

- Provide artificial hormones to the body
- Mask natural menstrual cycle
- Impact on exercise performance should be monitored on an individual basis

Types:

- Combined pill
- Progestin only pill (POP)
- Contraceptive patch
- Vaginal ring
- Implant
- Injection or "shot"
- Intrauterine device (IUD)



MENSTRUAL CYCLE DISRUPTION

Potential causes:

- Stress
- Using a hormonal contraceptive
- Low energy availability

Warning signs:

- Increase in menstrual cycle length
- No ovulation
- Reduction in amount of bleeding during period
- Period stops completely

HEAVY MENSTRUAL BLEEDING (HMB)

- One in three exercising females experience HMB
- More likely to feel that period negatively impacts training/performance
- Can reduce well-being and confidence
- More likely to suffer from an iron deficiency

Those experiencing HMB may:

Pass large blood clots	Need to change sanitary products frequently
Need to use two types of sanitary products at once	Have periods that last >7 days
Bleed through clothes	Often feel tired

NUTRITION

26 Fe

Regular menstruation = ↑ risk of being iron deficient. Optimize iron intake in daily diet.

No evidence to suggest changing diet depending on menstrual cycle phase. Focus on optimizing daily nutrition.

Low energy availability can lead to menstrual cycle disruption. Ensure daily energy intake matches daily energy demands.

Bone Health

GATORADE SPORTS SCIENCE INSTITUTE™

Introduction

Bone health is an important but often overlooked subject for athletes, as well as the general population. Bone density is a critical component to overall health and function throughout the lifespan. Maximizing bone mineral density is crucial because females are particularly susceptible to low bone mineral density, known as osteopenia and osteoporosis. The information below will provide a brief overview of bone physiology, growth and remodeling, the impact of energy and micronutrient intake on bone health, and practical applications to support athlete bone health.

Bone physiology

Structure

The human skeleton is made up of cartilage and bone. It provides the structure of the human body, protects vital organs, serves as an attachment point for muscles, and stores calcium. Bone is one of the hardest materials within the human body, yet it is also very light in weight. The composition of bone includes water, calcium phosphate in the form of hydroxyapatite, and protein in the form of collagen. The structure of healthy bones largely differs to that of osteoporotic bone (i.e., during osteopenia and osteoporosis, Figure 1).

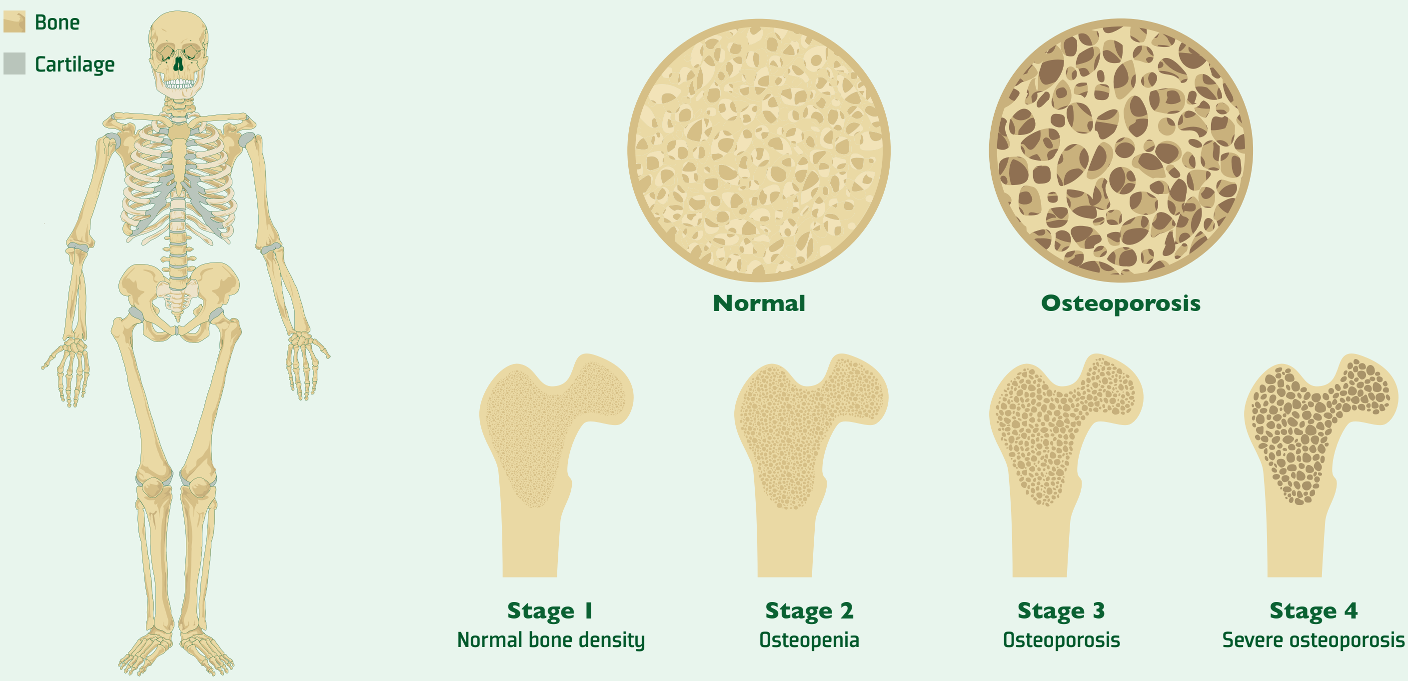


Figure 1: Normal bone vs. osteoporotic bone

Bone formation and turnover

Bone health is regulated by the endocrine system, with multiple hormones influencing the building, maintenance and breakdown of bone, including, but not limited to, parathyroid hormone (PTH) and estrogen. The following section describes the process when the endocrine system is functioning as designed, with adequate energy availability and micronutrient intake from the diet.

Bone modeling and remodeling

Bone modeling is the process of building new bone tissue, and bone remodeling is a process of continuous breakdown and formation (Figure 2). In youth, longitudinal bone modeling occurs at the sites of the epiphysial (growth) plates. Peak bone density is achieved in the first few decades of life. With mechanical loading, bone diameter can continue to grow into adulthood. Specific cells called osteoclasts, osteocytes and osteoblasts are responsible for development, growth and remodeling of bone tissue.

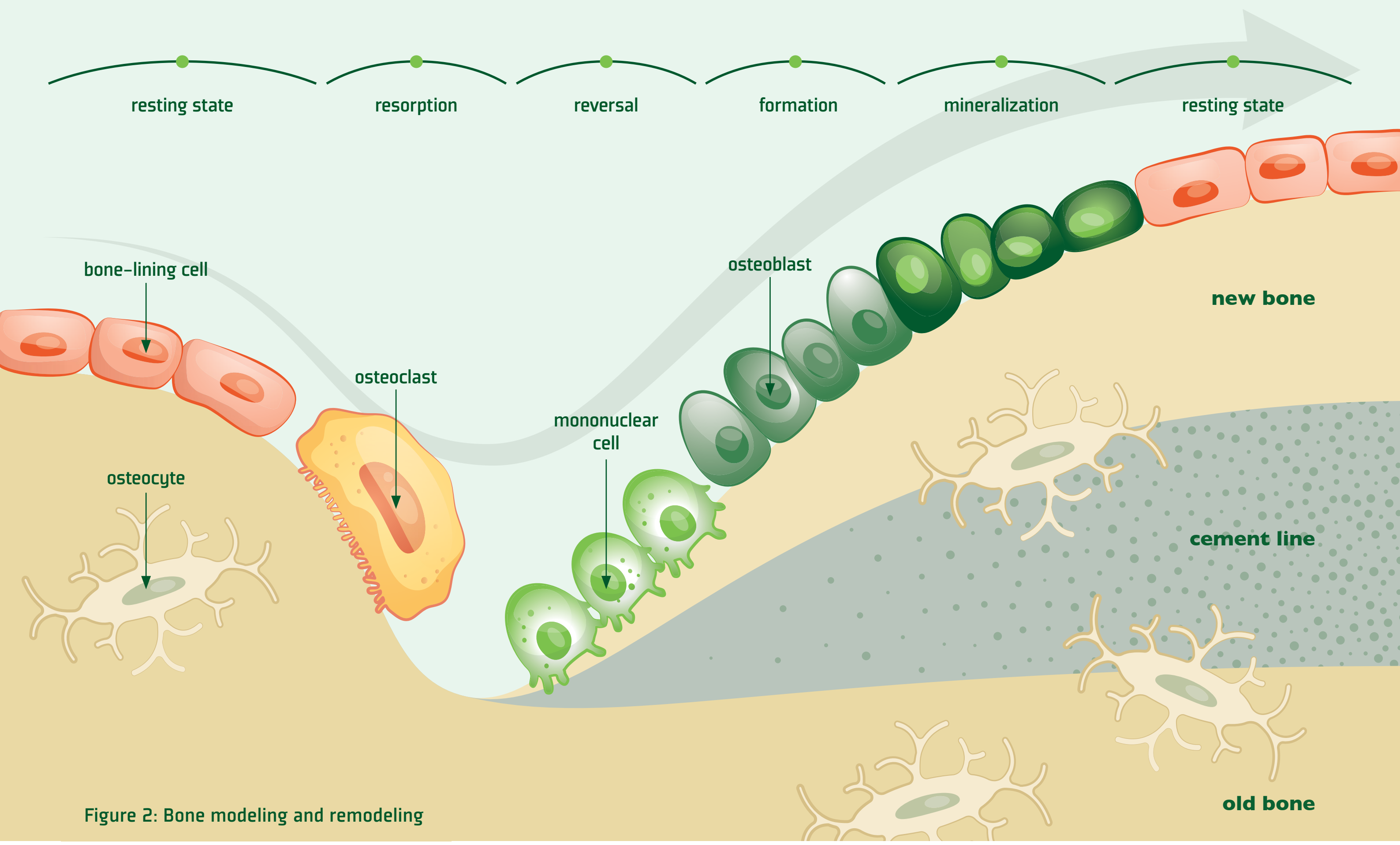
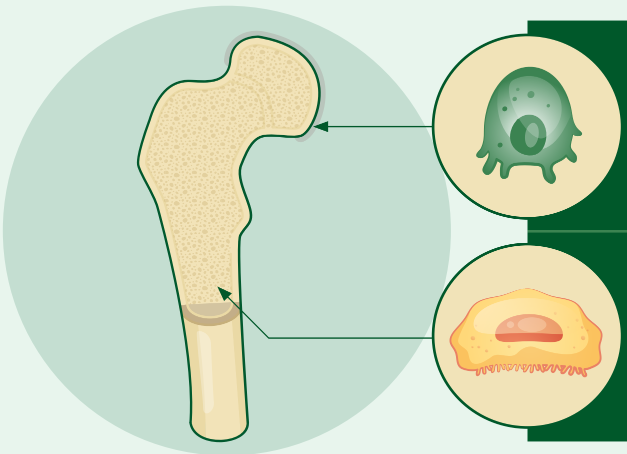


Figure 2: Bone modeling and remodeling

Osteocytes

Osteoctyes are the most common cells found within the bone tissue. They monitor the health of the bone and when stressors are placed on the bone. If the bone tissue becomes damaged, osteocytes are responsible for sending signals to the osteoclasts and osteoblasts, to remove damaged bone tissue and build new bone tissue, respectively.

Osteoblasts and osteoclasts



Osteoblasts	Grow new bone tissue Remodel bone tissue with age Heal damaged or broken bones Mineralization of bone
Osteoclasts	Take care of old or damaged bone tissue Release enzymes that dissolve old or damaged bone tissue Break down tissue identified by osteocytes

Osteoblasts are activated by hormones and deposit a bone matrix (collagen, calcium, phosphate and other minerals) onto areas of the bone that either need to grow or be repaired. The bone matrix then hardens to become new healthy bone. Once the new bone tissue has been laid, osteoblasts will either transform into osteocytes, or die. When old or damaged bone tissue is present, osteoclasts release enzymes that dissolve that bone tissue. Osteoclasts will only break down tissue identified by osteocytes.

Primary factors that impact bone remodeling

There are two primary factors that impact how the bone is remodeled and the strength of the bone throughout adulthood:

1 The availability of calcium in the blood

The human body tightly regulates serum calcium levels and will sacrifice bone tissue to maintain calcium homeostasis. Without adequate calcium ingestion, calcium is not available to be deposited into the bone tissue. In youth and early adulthood, if inadequate amounts of dietary calcium are consumed, bone formation may be compromised. In addition, existing bone tissue may be broken down to release stored calcium back into the blood to maintain serum calcium levels. Prolonged breakdown of bone tissue can compromise bone density in both youth and adulthood.

Dietary calcium intake is critical to supporting bone growth during youth and bone maintenance and health during adulthood. Foods and beverages high in calcium include:

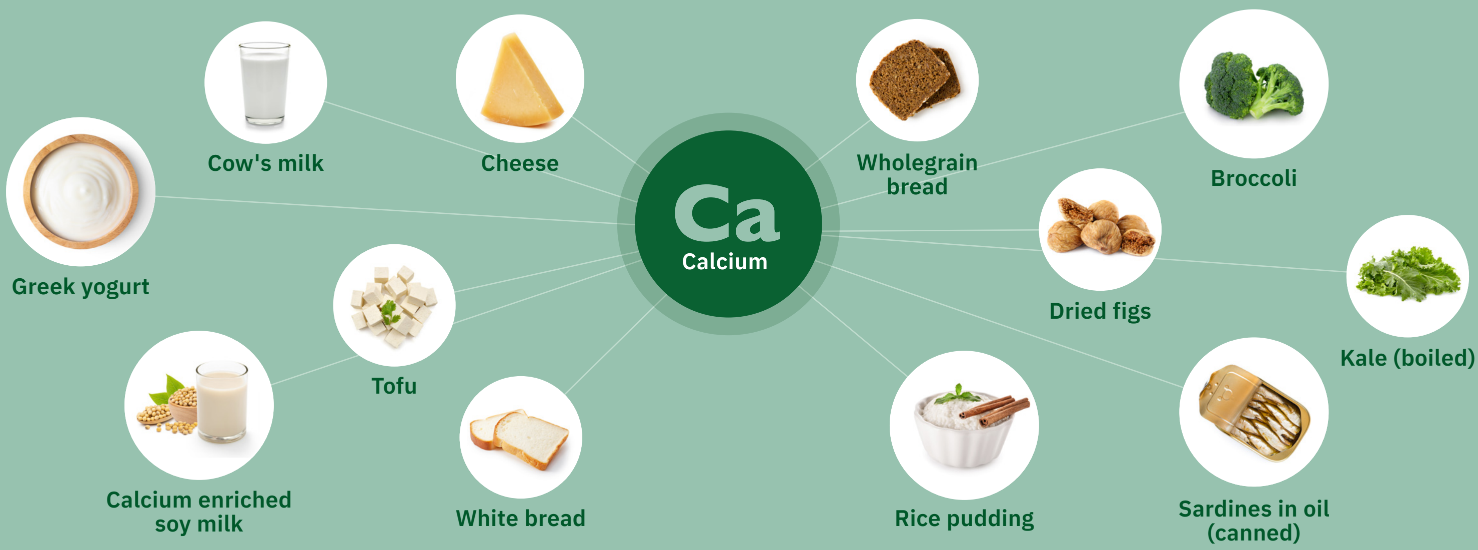


Figure 3: Foods rich in calcium

2 The pull of gravity and muscles on the skeleton

Exercise is classed as weight bearing when the person is on their feet and the skeleton is supporting their body weight. Exercises like walking, running, dancing, as well as sports involving running or jumping (e.g., tennis, soccer, basketball, etc), are all considered weight bearing. The mechanism of weight bearing activity causes muscles and tendons to put stress on the bone tissue. This stimulates bone formation and strengthens bones.

Bone health throughout the lifespan

Bone is a dynamic and active tissue. The greatest amount of growth in bone length and diameter occurs during puberty, until the epiphyseal (growth) plates close (Figure 4). During this period, over 90% of an individual's total bone density is acquired. Bone mass can also be accrued through the third decade of life through a combination of load bearing physical activity and adequate dietary intake. After this point, the focus shifts to the maintenance of bone mineral density.

Osteoporosis, and its pre-cursor osteopenia, are health conditions characterized by low bone mineral density. Osteoporosis is generally considered an aging disease. However if peak bone mineral density is not acquired during puberty, and there is continued inadequate energy and/or micronutrient intake, it is possible for athletes to develop osteopenia and osteoporosis at a younger age. Porous and brittle bones are not compatible with life as a competitive athlete and can cause an early end to promising careers.

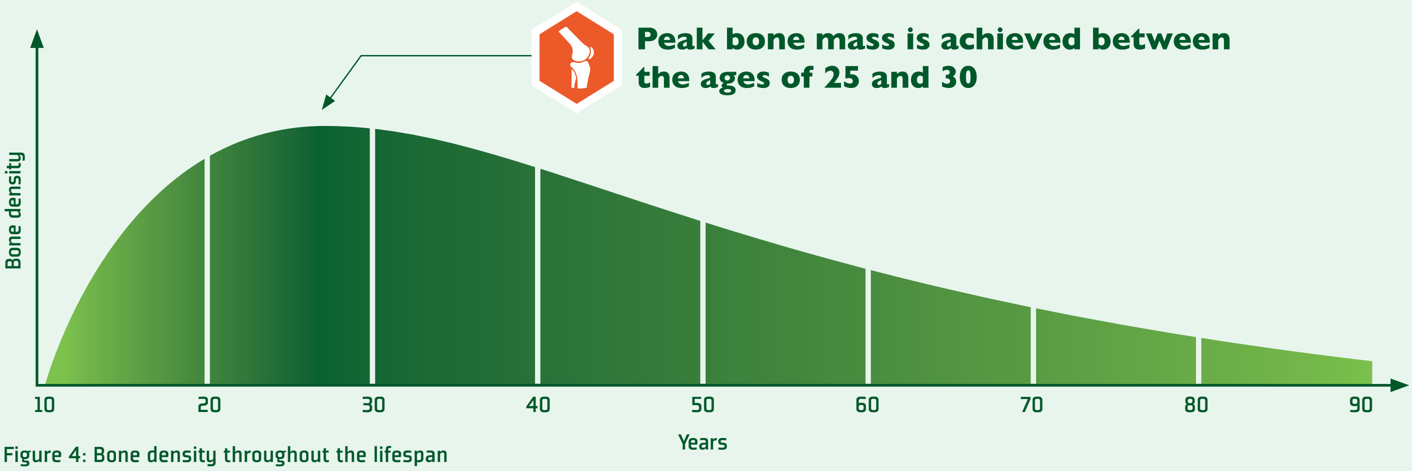


Figure 4: Bone density throughout the lifespan

Critical time points

Puberty

Throughout childhood and adolescence, cells called chondrocytes within the epiphysial plates are continuously producing new cartilage. The cartilage will ultimately be replaced by mature osteocytes when the epiphysial plates close. At the same time, modeling and remodeling of existing bone is also occurring. Bone modeling is closely related to the production of sex steroid hormones, particularly estrogen in females.

Menopause

Bone loss with aging is not an unexpected phenomenon, but effort should be made to minimize losses in bone mineral density. In females, estrogen production significantly decreases with the onset of menopause. This decrease, when combined with lack of weight bearing exercise and low intake of dietary calcium, vitamin D and magnesium, can significantly increase the risk of the development of osteopenia or osteoporosis. The risk is even greater if an individual already has weak and porous bones prior to menopause.

As over 90% of bone mineral density is acquired in the first two decades of life, providing adequate calcium to maximize bone density during this time is critical to lifelong bone health.

Nutrition and bone health

Energy balance

Adequate energy intake supports the overall health of bone. When in prolonged energy restriction, disruptions occur within the endocrine system that can ultimately have a negative impact on bone health. See 'Energy Availability' for more information on the impact of energy restriction on bone health.

Protein

Protein plays an important role in the production and action of Insulin-like Growth Factor (IGF-1), which is necessary for bone formation. IGF-1 stimulates the absorption of the bone mineral elements calcium and phosphate in the intestines, as well as the renal tubular reabsorption of phosphate. Without adequate protein intake during puberty, the production and action of IGF-1 are impaired, which can negatively impact bone mineral density.

In older athletes, particularly post-menopause, bone strength is positively correlated with greater dietary protein intake. In addition to bone health, adequate protein intake with aging can also reduce the risk of muscle weakness and loss (sarcopenia).

Micronutrients

There are several micronutrients which are key for bone health. Figure 5 shows dietary sources of each of these micronutrients, and Table 2 discusses these micronutrients in further detail.

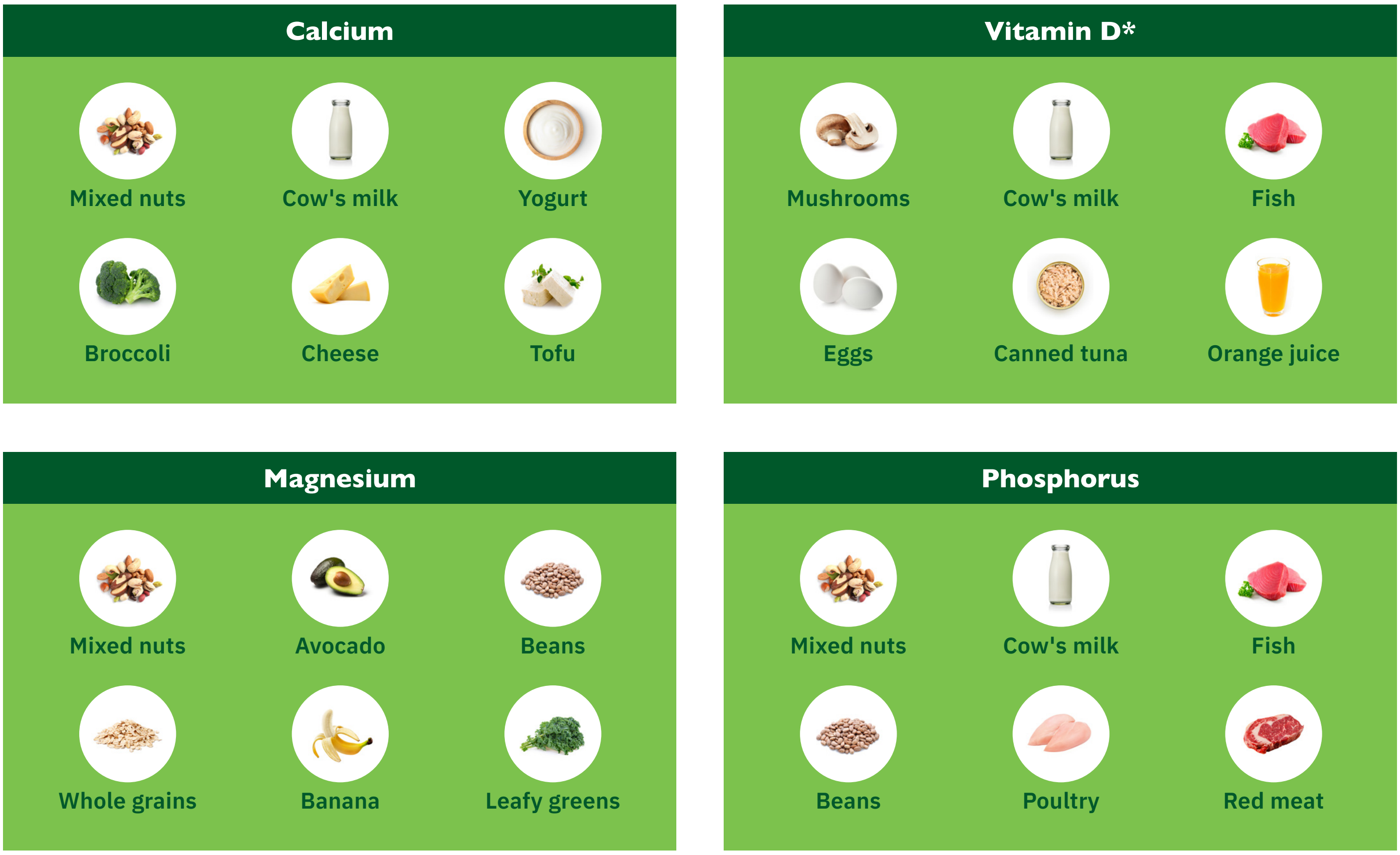


Figure 5: Dietary sources of key micronutrients for bone health

*Due to the limited number of natural sources of vitamin D and limited exposure to UV rays from the sun, supplemental intake of vitamin D3 may be warranted after consulting with a physician. See the vitamin D section of 'Micronutrients' for more detail.

Table 2: Functions of various micronutrients, and consequences of insufficient/excess intakes

	Function	Insufficient intake	Excess intake
20 Ca **Calcium**	Calcium is the primary mineral found in bone tissue. When adequate calcium is consumed during both the development and maintenance phases of bone formation, bone mineral density is maximized and subsequently the integrity of the bone is maintained throughout the lifespan.	When serum calcium falls below a certain level and no exogenous calcium is consumed, the calcium that is stored within the bone can be removed to maintain serum calcium homeostasis. Continuous removal of calcium is detrimental to the integrity of the bone structure if not replaced.	Hypercalcemia (too much calcium in the blood) is most frequently caused by issues with the parathyroid hormone, or other medical conditions. Excess supplemental intake of calcium (>2000 mg/d) can also cause hypercalcemia which, in turn, can cause weakness in the bone or bone pain.
Vitamin D	Vitamin D is a critically important micronutrient for bone health. Vitamin D and its metabolites are a key component to endocrine regulation of serum calcium through the mechanisms of intestinal absorption, stimulating the breakdown of bone tissue and renal absorption of calcium.	Inadequate Vitamin D intake and subsequent Vitamin D deficiency negatively impacts the regulation of calcium, which can result in poor bone health. Other symptoms of Vitamin D deficiency include muscle weakness, muscle aches, fatigue, joint pain, and increased susceptibility to illness.	Toxicity is rare but generally occurs with excessive supplemental intake of Vitamin D. Hypervitaminosis D can result in hypercalcemia in the blood due to disruptions in calcium regulation.
12 Mg **Magnesium**	From an endocrine standpoint, magnesium indirectly impacts bone health because it is an essential co-factor in the activation of Vitamin D (1,25[OH]2D or calcitriol). Consuming adequate amounts of magnesium is necessary in order to achieve the optimal benefits of Vitamin D.	Based on NHANES data, nearly half of all Americans consume less magnesium than recommended. Diagnosing a magnesium deficiency is difficult though since serum magnesium status does not always reflect total body magnesium.	Toxicity generally occurs with excess supplementation of magnesium, or in individuals with renal issues. Excess magnesium intake from food does not pose a risk in healthy individuals because the kidneys eliminate excess amounts in the urine.
15 P **Phosphorus**	Phosphorus is another mineral involved in the mineralization of bone tissue as part of hydroxyapatite. Approximately 85% of phosphorus in the human body is found within the skeleton. It is a necessary mineral for osteoblasts to work and osteocytes to form.	Phosphorus deficiency is rare in adults. According to NHANES data, most Americans consume more than the recommended daily intake for phosphorus.	Excess phosphorus intake may lead to hypocalcemia or low serum calcium due to the affinity of phosphorus for binding to calcium in the digestive tract, reducing calcium absorption and availability for building bone structure. High dietary phosphorus intake may also increase PTH secretion, which in turn can lead to increased bone resorption or breakdown to release calcium into the bloodstream.

Practical suggestions

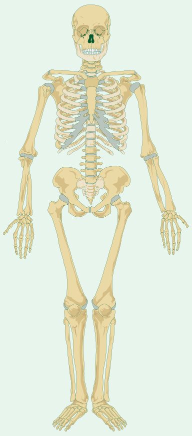
Adequate energy intake can help to minimize the risk of micronutrient deficiencies, particularly when a wide variety of foods are consumed.

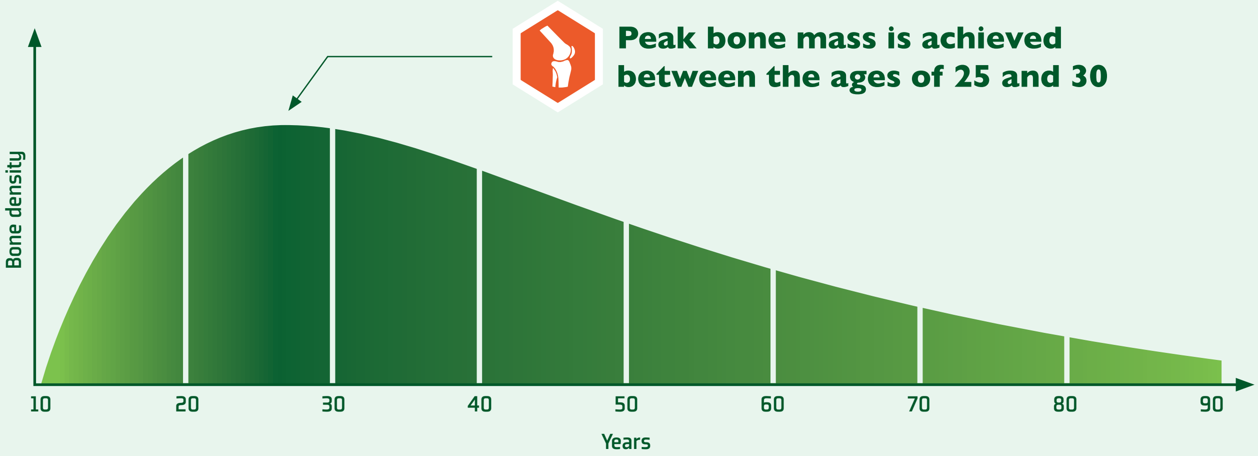
Female athletes should be encouraged to eat regularly throughout the day, between 4-6 meals including multiple food groups at each meal.

Protein intake is also critically important when it comes to developing and maintaining bone mineral density. It is highly recommended to screen female athletes for low energy availability/REDs, particularly those at high risk. This can help to identify athletes who are in need of intervention and education.

BONE HEALTH

Bone health is extremely important for female athletes





Primary factors impacting bone remodelling and strength

Level of calcium in the blood

Dietary calcium intake is critical to supporting bone growth during youth and bone maintenance and health during adulthood

Pull of gravity and muscles on the skeleton

Weight-bearing exercise causes muscles and tendons to put stress on the bone tissue, which stimulates bone formation and strengthens bones

Nutrition and bone health

Energy balance

Adequate energy intake supports the overall health of the bone

Protein

In adults, bone strength is positively correlated with greater dietary protein intake

Calcium

Adequate calcium consumption maximizes bone mineral density

Vitamin D

Key component for endocrine regulation of serum calcium

Magnesium

Adequate magnesium intake is necessary to achieve the optimal benefits of Vitamin D

Phosphorus

Involved in the mineralization of bone tissue, necessary mineral for osteoblasts to work and osteocytes to form

Dietary Supplements

Introduction

The prevalence of supplement use in athletes is high, ranging from 40 to 100% depending on the type of sport and competitive level. Supplement use is reported to be higher in female athletes compared to males. However, females tend to consume more vitamin and mineral based supplements, whereas males are more likely to use supplements associated with improving muscle mass (e.g., creatine and protein powder). In addition, supplement use is greater in elite athletes, compared to non-elite, as well as those competing in endurance-based sports (compared to other sports).

The information below will focus on ergogenic supplements (i.e., those intended to enhance performance) that may be beneficial to female athletes, and how they can be used safely. It is important to emphasize that a cost/benefit analysis should be completed by a qualified professional, in consultation with the athlete, before an athlete uses a supplement. The athlete's needs, preferences, and sport type should be considered, amongst other factors.

- 40-100% of athletes use supplements
- Supplement use higher in elite vs. non-elite
- Supplement use higher in females vs. males
- Females tend to use more vitamin and mineral based supplements

Safety and quality assurance

The supplement market continues to grow exponentially, with many supplements using exaggerated claims. The supplement industry is not universally regulated and, as supplements are used extensively within the athletic population, the possible contamination and/or adulteration of supplements with prohibited substances puts athletes at risk of breaking anti-doping legislations. The World Anti-Doping Association (WADA) openly states that athletes are responsible for anything that is found within their body, and supplement use should align with the WADA code of conduct. Therefore, appropriate steps must be taken to reduce the risk of an athlete producing a positive doping test result, and a cost/benefit analysis should be completed and guided by a qualified professional.

Quality assurance is also essential to ensure safe supplement use. There are several quality assurance programs available, for example NSF Certified for Sport. This third-party organization batch tests supplements provided by manufacturers and ensures that products do not contain unsafe levels of contaminants, or prohibited substances, and that the label matches what is in the product. Should an athlete wish to use a supplement, it is strongly recommended that they purchase it from a manufacturer that uses one of these quality assurance programs. However, while these programs provide considerable protection, they are not an absolute guarantee of supplement quality.

Athlete supplement safety

Advice should be obtained from a qualified professional	Supplement use should be in line with the WADA code	Supplements should only be purchased from companies that use a quality assurance program	Recommended doses should not be exceeded

Figure 1: Ensuring supplement safety with athletes

Supplement use decision tree

The flow chart below can be utilized to ensure the athlete makes an informed decision on consumption of an ergogenic supplement (i.e., a supplement aimed to enhance athletic performance).

Is the athlete ready for supplement use?
- What are the athlete's performance goals?
- Is the supplement appropriate for the athlete's age/maturation/experience?
- Have all other dietary approaches and relevant training variables been considered?

NO/NOT KNOWN → DO NOT USE

YES ↓

Is the supplement effective in the sport of interest?
- Consider the level and quality of evidence from scientific studies and/or meta-analyses or established scientific 'track record'

NO/NOT KNOWN → DO NOT USE

YES ↓

Is the supplement safe for the athlete to consume?
- Has the athlete had any previous adverse reactions?
- Is the athlete taking any medications that the supplement could interact with?
- What dose is required?

NO/NOT KNOWN → DO NOT USE

YES ↓

Is there a reliable source of the supplement?
- Ensure no WADA prohibited substances identified on label
- Known manufacturer with good history and practice?
- Tested by established quality assurance program?

NO/NOT KNOWN → DO NOT USE

YES ↓

Use supplement on a trial basis
Trial in practice and/or less important competition

↓

Consistent positive results?

NO/ADVERSE EVENT → DO NOT USE

YES ↓

Continue supplement use

Adapted from Maughan et al. (2018)

Creatine

Creatine is an amino acid mainly located in skeletal muscle (95%), with small amounts located in the brain. Creatine is produced endogenously in the liver and the brain, however it can also be consumed within the diet through foods like fish and red meat, or it can be supplemented (as creatine monohydrate).

Oral creatine monohydrate supplementation has been found to improve high-intensity exercise. This is by increasing skeletal muscle stores of free phosphocreatine, by as much as 20–40%, which can then be used to produce and maintain energy.

Supplemental creatine is primarily recommended for athletes who play sports that require quick bursts of power or strength (e.g., weightlifting), or sports that involve repeated high-intensity intermittent running (e.g., team sports).

Females have higher endogenous muscle creatine concentrations in comparison to males (relative to tissue mass). It has been suggested that individuals with high muscle creatine levels might have a smaller positive response to creatine supplementation. However, a meta-analysis found female participants to have greater relative improvements in performance variables from baseline compared to males when supplemented with creatine monohydrate. The data here is limited and of low quality, however it does suggest that daily supplementation of creatine monohydrate may be beneficial to female athletes.

In addition to increasing energy stores, other benefits of creatine supplementation include:

- Increased muscle strength and power in response to training via possible increased gene expression and increased intracellular water, as well as enhanced recovery from muscle damaging exercise.
- Improved bone health: preliminary research in older adults has found that the combination of creatine supplementation and resistance training can have positive effects on bone tissue by altering the bone remodeling process. It is possible that creatine supplementation may also benefit the bone health of athletes.
- Enhanced cognitive function: there is also emerging evidence that creatine may benefit certain aspects of cognitive function, such as improved memory, and the ability to maintain cognitive function when the brain is stressed (e.g., sleep deprivation or mental fatigue). Thus, creatine supplementation might be a consideration for athletes to use strategically during certain phases of the season i.e., intense periods of competition.

Guidance

Two dosing protocols can be used for creatine supplementation:

1. ‘Loading phase’ of 4 x 5 grams/day for 5-7 days followed by a ‘maintenance dose’ of ~5 grams/day
2. Longer duration ‘maintenance dose’ of ~5 grams/day

If using in powder form, creatine can be taken within a meal or snack e.g., by adding the powder to oatmeal or a smoothie, or mixing the powder into a drink. If using in tablet form, it can be swallowed with a drink.

Consideration

The ‘loading phase’ is often associated with weight gain due to an increase in skeletal muscle water retention. Therefore, for athletes who may be more concerned with gaining weight, the second protocol may be more appropriate. It is worth noting that this response is individual and may potentially not be as evident in females compared to males.

Cycling creatine supplementation throughout a season

Athletes may wish to 'cycle' creatine supplementation throughout a season (Figure 2). This is because it takes weeks for body creatine stores to return to baseline levels once stopping supplementation. If they do this, then the athlete may wish to take creatine during specific stages of the season e.g., pre-season and during periods of competition. This figure shows an example of how the athlete could cycle creatine during their season. This can be adapted to fit the season of the sport that the athlete competes in. It should be noted that cycling creatine supplementation is not essential and is down to individual preference.

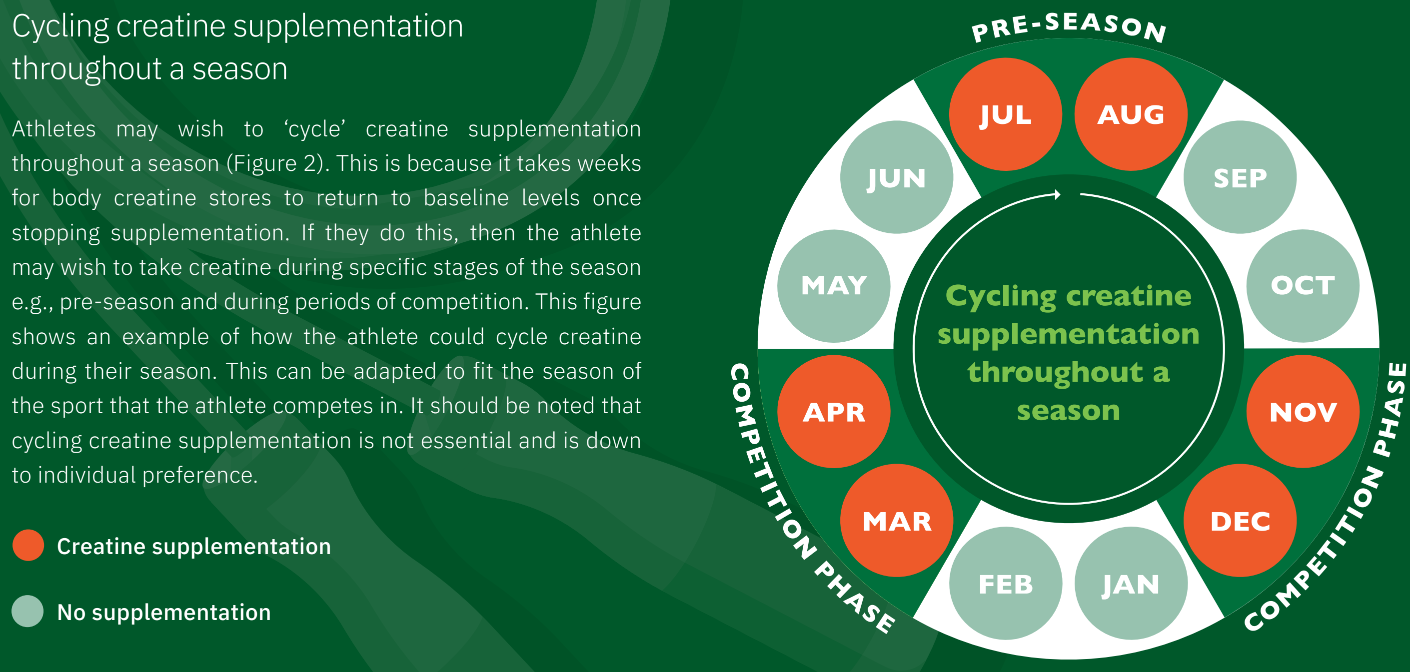


Figure 2: Cycling creatine supplementation

Protein powder

The macronutrient protein is an essential part of an athlete's diet. It is beneficial for building muscle mass, as well as recovering post-exercise.The majority of an athlete's protein intake should come from food sources however, it can sometimes be difficult to meet the elevated daily protein requirements for athletes, particularly when travelling or during periods of intense training or competition. Protein powder provides a convenient and simple way to increase daily protein intake, which can be used as an 'on-the-go' post-exercise snack and/or to supplement the diet, however it should not be used as a meal replacement alternative.

Whey, soy, casein, or plant-based protein blends containing all EAAs are are generally recommended for athletes because they are all considered 'complete' sources of protein (meaning that they contain all nine essential amino acids, including leucine which is an important amino acid for triggering muscle protein synthesis). For athletes following plant-based diets, soy or plant-based protein blends are suitable options.

Protein powder can be used in a variety of ways including:

- Mixed with water or milk
- Mixed into oatmeal or yogurt
- Blended into a smoothie
- Used as an ingredient in recipes e.g., pancakes, muffins, banana bread

Guidance

Servings of 20-40 grams (which usually equates to ~1 scoop) at a time

If the athlete is combining protein powder with other high protein foods e.g., milk or yogurt, then the amount of protein powder can be reduced so that the total meal/snack protein serving equates to 20-40 grams.

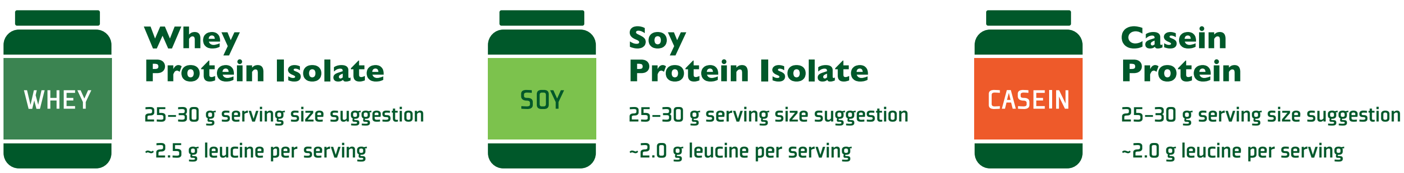


Figure 3: Protein powder examples

Caffeine

Caffeine is widely used by athletes, with data reporting that ~75% of elite athletes use it as an ergogenic supplement. It is also one of the most studied supplements and has been shown to enhance athletic performance. Although the mechanisms by which caffeine exerts its performance enhancing effects are not fully known, it is thought that caffeine acts as an adenosine receptor antagonist. This results in increased central drive in the central nervous system, as well as decreased perceptions of effort and pain in the parasympathetic nervous system.

Potential benefits of caffeine supplementation

- Improves aerobic endurance exercise
- Reduces feelings of fatigue
- Improves cognitive function
- Improves repeated sprint performance

It is recommended that practitioners work with athletes to practice using caffeine in and around training sessions prior to using it on the day of a competition. This is because it allows time to practice with different doses to find out the optimal dose for the athlete (see below). In addition, it gives an understanding of any side effects that the athlete may experience, and if so, whether it may negatively impact performance. Finally, it allows time to understand the impact that it may have on the athlete's sleep, and therefore their recovery.

Guidance

3-6 mg of caffeine per kg of body mass, ~60 minutes pre-exercise (depending on the form of caffeine used)

The minimum dose of caffeine to induce performance enhancing effects is most likely ~2 mg of caffeine per kg of body mass, but it is likely to differ between individuals.

Calculating individual recommendations:

~60 minutes prior to exercise:

_______ body mass (kg) * 3 mg = _______ mg

_______ body mass (kg) * 6 mg = _______ mg

Consideration

Athletes must be aware of the adverse effects caused by consuming too much caffeine (e.g., headaches, anxiety, confusion, irritability, stomach discomfort, tachycardia) which can impact their performance.

Practical strategies

Athletes can slowly work up to the recommended amount of 3-6 mg/kg BM to establish the dose that they can best tolerate. To do this, an athlete can begin by ingesting a low amount of caffeine (e.g., ~1 mg/kg BM) before a training session, and then their responses can be evaluated (both physical and cognitive), as well as any adverse effects recorded. If this amount is tolerated, they can begin to gradually increase their caffeine dose in small increments until they find the most appropriate dose.

When deciding whether to use caffeine, athletes should take into account that caffeine will remain in the system for ~3-5 hours afterwards, which could have a negative impact on their sleep. If the exercise occasion is late in the day, athletes may want to consider adjusting their caffeine intake to an earlier time, or not using caffeine at all.

Sources of caffeine

There are various ways in which caffeine can be consumed (see below). It can be difficult to know the exact caffeine content of coffee because many factors can have an influence, including the brewing method, type of bean and quantity of coffee grounds used. Sports nutrition products containing caffeine (e.g., tablets, gums, or gels) will state the caffeine content on the packet, making it easier to know the exact amount being consumed. It is important to note that caffeine in caffeinated gum is absorbed more quickly in comparison to other forms, therefore it should be ingested ~5-15 min prior to exercise.


Coffee


Caffeine tablets


Caffeine gum


Sports gel containing caffeine

Sex differences

Females may have different metabolic responses to caffeine in comparison to men, and all individuals will respond differently. It is suggested that caffeine elimination is slower during the luteal phase of the menstrual cycle, and with oral contraceptive use. This accumulation of caffeine during high estrogen phases of the menstrual cycle may intensify the sympathetic effects of caffeine, as well as enhance pre-menstrual symptoms. Studies suggest that caffeine may decrease the perception of pain in females, which may allow for higher intensity and/or longer duration training sessions to be completed, resulting in greater physiological adaptations. However, more research is needed.

Beta-alanine

Beta-alanine (β-alanine) is a substrate of carnosine. Carnosine is an intracellular buffer which can reduce the development of muscle acidosis during intense exercise, through slowing the decline in muscle pH. As carnosine absorption by the intestine is not very effective, and β-alanine is rate limiting for carnosine synthesis, supplementation of β-alanine is required for increased plasma carnosine levels which can result in potential performance benefits.

Studies have shown that β-alanine can provide performance benefits during continuous (1-7 minutes) high-intensity exercise, where the main mechanism of energy production is predominantly glycolysis.

Examples of events where β-alanine may be beneficial are 200m swimming, 800m running, 4 km time-trial cycling, and 2000m rowing. However, most of these studies have investigated male athletes, with limited data available on female athletes. The data available in female athletes suggests that β-alanine may act as an ergogenic aid by delaying the onset of fatigue and lowering ratings of perceived exertion during exercise. Therefore, allowing exercise to be completed at a higher intensity, producing greater physiological adaptations and improving performance.

Consideration

Daily β-alanine doses are administered in multiple servings to minimize side effects, such as paresthesia (itching/tingling of the skin).

β-alanine (intracellular buffer) can be combined with an extracellular buffer (e.g., sodium bicarbonate) to provide an additive effect on performance. However, there is the possibility that gastrointestinal distress may occur.

Guidance

~3-6 g of β-alanine per day, administered as servings of ~0.8-1.6 g every 4 hours, for at least 4 weeks

This should be followed by a maintenance dose of 1.2 g per day.

Nitrate

Recent studies have shown that inorganic (dietary form) nitrate can enhance general health, as well as athletic performance. Nitrate can be obtained from dietary sources (Figure 4), however these food sources often require a large amount to be eaten before nitrate recommendations (6.5-13 mmol / 400-800 mg) are attained, therefore sports supplements (e.g., beetroot juice) are recommended as an alternative.

Guidance

6.5-13 mmol / 400-800 mg 2-4 hours before exercise

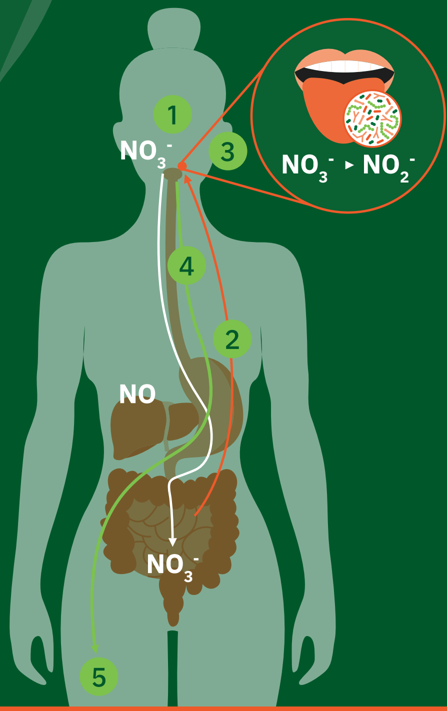
This is equivalent to 1-2 beetroot juice shots.

Figure 4: Foods rich in nitrate and their nitrate values (per 150g/5 oz serving)

How does nitrate supplementation work?

Nitrate supplementation works via second pass metabolism:

1. Nitrate (NO_3^-) is ingested
2. Nitrate (NO_3^-) passes into the blood stream and is delivered to the salivary glands to be secreted into the mouth
3. Using some species of bacteria in the oral microbiome, nitrate (NO3-) is reduced to nitrite (NO_2^-)
4. Nitrite (NO_2^-) is absorbed and converted into nitric oxide, which leads to the formation of other nitrogen intermediates that can then pass into the bloodstream and increase vasodilation
5. This has been found to improve muscle calcium handling and contractile function in skeletal muscle, which in turn can improve performance



Studies suggest nitrate supplementation improves:

- Endurance exercise performance
- All-out sprint exercise
- High-intensity intermittent exercise (e.g., team sports)

Mechanisms

Nitric oxide (NO) plays a role in other physiological processes including mitochondrial efficiency, neurotransmission, and muscle oxygen delivery. Nitrate supplementation might be beneficial for athletes because the enzymes that convert nitrite into NO are activated to a greater extent as acidosis and hypoxia develop in the blood and muscle, which occurs during intense exercise. Therefore, the NO pathway is enhanced during situations of acidosis and hypoxia (i.e., during intense exercise). Due to females having smaller blood vessels and a greater ability to reduce nitrate to NO compared to males, it is possible that nitrate supplementation may be more effective in females. In addition, there is some evidence to suggest that females have a better ability to generate NO through greater activation of the enzyme nitric oxide synthase, due to the stimulatory effect of estrogen on nitric oxide synthase. However, specific research on nitrate supplementation in females is very limited, with mixed results as to whether nitrate enhances performance.

Consideration

Athletes should refrain from using antibacterial mouthwash when supplementing with nitrate as it limits the metabolism of nitrate to nitrite by the microbiome.

Important

More research is needed with groups of recreationally active and elite female athletes, in varying menstrual states, with varied nitrate doses and durations, as well as different exercise modalities and durations.

Safe supplement use

Supplements that are offered across the sports nutrition industry continue to evolve. In an ever-changing landscape, it is important that athletes make educated choices to safeguard their health and well-being. Manufacturers can use promotional materials and non-substantiated claims that target female athletes, including 'helps you to lose weight', 'improves hormone balance', 'burns fat', 'increases energy', or 'helps you to stay healthy'. It is important to note that the scientific evidence to support these claims is often lacking, and ingesting these supplements might be harmful to health and performance.

Dietary supplementation should always be led by a qualified professional (e.g., a sports dietitian). It is encouraged to monitor the effectiveness of any supplement program via tracking changes in either health or performance indicators. Finally, athletes should always ingest supplements before, during or after training (depending on the supplementation protocol) to evaluate any potential negative side effects, prior to implementing supplement use around a competition.

DIETARY SUPPLEMENTS

	Benefits	Sports	Guidance
Creatine	• Increases muscle strength and power • May benefit cognitive function when sleep deprived or mentally fatigued • May have positive effects on bone tissue	High intensity, intermittent exercise Strength and power sports	**Option 1:** **4x 5 g/day for 5-7 days, followed by ~5 g/day** **Option 2:** **~5 g/day** *Potential weight gain (due to skeletal muscle water retention) is highly individual and may potentially not be as evident in females compared to males*
Protein powder	• Convenient and simple way to increase protein intake • Supports performance and recovery needs	Appropriate for all sports	**Per serving: 20-40 g** **Whey, soy, casein, or plant-based protein blends containing all EAAs**
Caffeine	• Reduces feelings of fatigue • Improves endurance exercise and repeated sprint exercise • Improves cognitive function	Endurance exercise Repeated sprint exercise	**60 min pre-exercise:** **3-6 mg of caffeine per kg of body mass** **Be aware of adverse effects of consuming too much caffeine**
Beta-alanine	• Reduces development of muscle acidosis • Delays onset of fatigue and lowers ratings of perceived exertion	Continuous (1-7 minutes) high-intensity exercise	**For 4 weeks:** **~3-6 g/day of β-alanine, in servings of ~ 0.8-1.6 g every 4 hours** **Followed by a maintenance dose:** **1.2 g/day**
Nitrate	• Lowers blood pressure and increases vasodilation • Increases transportation of molecules to/from working muscle • Improves mitochondrial efficiency, neurotransmission and calcium handling	Endurance exercise High intensity sprints High intensity, intermittent exercise	**2-4 hours pre-exercise:** **6.5-13 mmol / 400-800 mg (or 1-2 beetroot juice shots)**

Gut Health

Introduction

Gastrointestinal (GI) complaints among athletes include upper GI (e.g., acid reflux) and lower GI (e.g. constipation or loose stool) symptoms, and can be caused by a multitude of factors such as under fueling, underlying GI disorders (like celiac or Crohn's disease), malabsorption, or inappropriate fueling around exercise. The etiology of exercise-induced GI symptoms is multifactorial, and can occur due to many factors, including training status, exercise type, nutritional status and fueling. Research has shown anywhere between 30-90% of athletes suffer from GI symptoms ranging from bloating to constipation, loose stool and more, with symptom severity and occurrence found to worsen with higher intensity exercise. GI issues and complaints are extremely common among female athletes with research reporting a greater prevalence of GI symptoms at rest, when compared to male athletes, but not during exercise. Female athletes also report greater incidences of GI complaints during menstruation.

Furthermore, there appears to be a relationship between female sex hormones (e.g., estrogen), the gut, and the brain. However, more research is needed regarding the link between these biological processes and how it might affect female athlete gut health.

The gastrointestinal (GI) tract

The GI tract consists of the mouth, esophagus, stomach, small and large intestines, and the rectum (Figure 1). The main functions of the GI system include ingestion and digestion of food, absorption of nutrients, water and enzyme secretion, and excretion of waste products.

GI issues during exercise

Exercise-induced GI symptoms (Table 1) can occur due to a number of factors such as reduced blood flow to the gut during exercise, mechanical stress and stress response. The extent of symptoms experienced can be dependent on variables such as the exercise intensity, duration and modality, the environmental conditions and dietary intake. As a result, gut function and motility are reduced, as well as nutrient digestion and absorption.

Table 1: Exercise-induced gastrointestinal symptoms

Upper abdominal symptoms	Reflux/heartburn
	Belching
	Bloating
	Stomach pain/cramps
	Vomiting
	Nausea
Lower abdominal symptoms	Intestinal/lower abdominal cramps
	Flatulence
	Urge to defecate (urgency)
	Diarrhea

The gastrointestinal tract

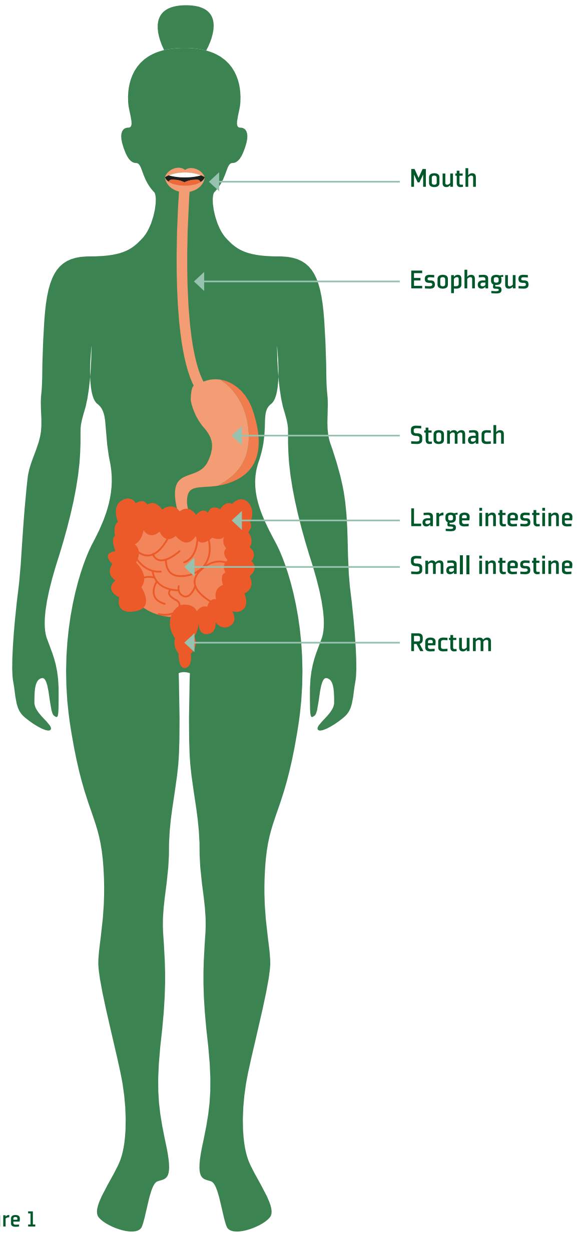


Figure 1

The following information will discuss common upper and lower GI symptoms and diseases, food intolerances, as well as practical advice for practitioners working with female athletes who are experiencing GI complaints.

Upper GI symptoms and treatments

Gastroesophageal reflux disease (i.e., acid reflux)

This is the most prevalent upper GI complaint in athletes. It occurs when acid from the stomach backs up into the esophagus, which can cause a burning sensation in the esophagus, feelings of nausea, and a sore throat. The frequency of symptoms depends on the strength of the lower esophageal sphincter and the acid production level in the stomach. Common symptoms of include:

- Painful swallowing
- Coughing
- Heartburn
- Regurgitation
- 'A lump in the throat'

Research has found a high prevalence of acid reflux at rest and during exercise in runners, cyclists, weightlifters, rowers, gymnasts, and American football players. However, more research is needed to understand the occurrence rates in other sports. For many athletes, changing fueling habits around exercise can help to alleviate symptoms. Consuming easier to digest foods (e.g., banana vs. acid producing foods such as citrus or chocolate) on higher intensity training days can help to decrease symptoms. In addition, athletes should be encouraged to consume low fat and low fiber meals prior to exercise as opposed to high fat and high fiber meals.

Nutrition and mental health interventions include:

- Working with a sports dietitian to find trigger foods for symptoms
- Being mindful of single sitting high fat meals
- Being aware of speed of meal and snack consumption
- Waiting 1-2 hours before laying down horizontally after eating
- Increasing water consumption throughout the day
- Decreasing stress
- Reducing caffeine and alcohol consumption
- Being mindful of non-steroidal anti-inflammatory (NSAID) use as this has been shown to cause increase symptoms
- Reducing the consumption of acidic foods such as tomatoes, tomato sauce, and spicy foods
- Hypnotherapy or meditation

If nutritional or mental health interventions do not alleviate symptoms, then the most common treatment is proton pump inhibitors which can help reduce acid production. However, it is important that an athlete consults a primary care physician or Gastrointestinal (GI) Doctor to discuss utilizing this medication.

Gastroparesis

Gastroparesis is defined as delayed motility of the stomach which causes changes in stomach emptying and digestion. The vagus nerve controls how food moves through the digestive tract. When the vagus nerve and stomach are functioning normally, the stomach should produce wave-like movements, known as peristalsis, which helps food move from the stomach toward the pyloric sphincter and into the small intestine where digestion continues. Gastroparesis occurs when the vagus nerve is damaged and/or stops working, which causes food to move too slowly, or it can stop moving completely (Figure 2).

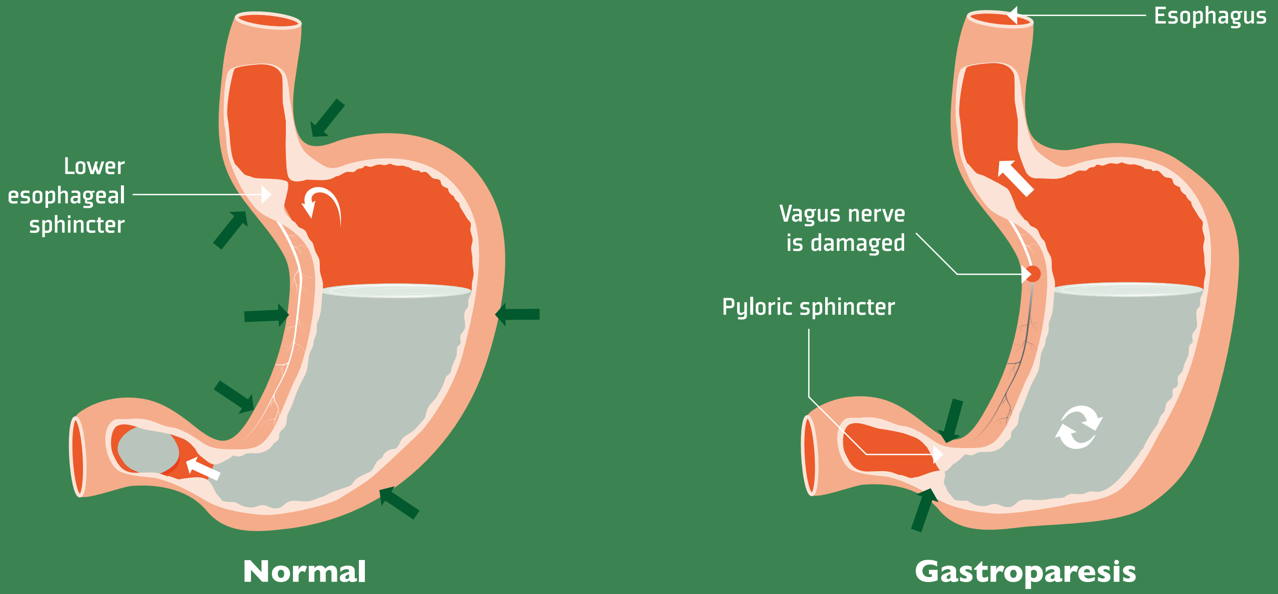


Figure 2: The stomach during normal functioning and gastroparesis

Potential symptoms of gastroparesis

- Bloating*
- Early satiety*
- Abdominal pain
- Abdominal distention
- Gas
- Constipation
- Loose stools
- Acid reflux
- Perception of consuming a "very large meal" when it was either normative or small
- Feeling full for long periods of time
- Nausea or vomiting

*most common symptoms

Diagnosing gastroparesis

Gastroparesis can be diagnosed medically through a gastric emptying study. However, a gastric emptying study is not always needed if the patient is complaining of symptoms, restricting intake, and in some cases has also lost weight. Under resting conditions, females have been shown to have slower gastric emptying and colonic transit times, compared to males, thus gastroparesis is more common in females, but there is a large inter-individual variability.

Gastroparesis can be seen in all body shapes and sizes, not just in underweight athletes. In many cases an athlete will decrease their intake with the intent of minimizing symptoms, but unfortunately it may do the opposite. Diagnosis of an eating disorder/disordered eating can be seen during gastroparesis diagnosis, and therefore it should be screened for in those experiencing gastroparesis. Restrictive behaviors tend to down regulate the energy it takes to digest food, making food take longer to move through the stomach.

Managing gastroparesis

- Start with 5-6 smaller meals and work up to larger meals
- Utilize fluid calories e.g., smoothies
- Limit consumption of high fiber-containing foods (e.g., fruit, vegetables, and whole grains) while intake is increased, as they can increase fullness and bloating
- Medications such as metoclopramide can be utilized short-term to reduce discomfort while intake is increased

It should be noted that the introduction of increased intake can cause **temporary discomfort** – this process can take weeks to months. Athletes should be supported by a dietitian/medical team throughout this process.

Lower GI symptoms and treatments

Constipation

Constipation is defined by having two or more of the following symptoms, occurring at least 25% of the time over a three month period:

Feelings of incomplete stool evacuation	Lumpy or hard stool	Straining

Constipation can be attributed to numerous things including hormonal changes, gastroparesis, decreased hydration, and a low dietary intake. The Bristol Stool Chart™ is a medical diagnostic scale used to identify and classify stool into groups, and monitor bowel movements by shape and type (Figure 3). Types 1 and 2 are more difficult to pass and may indicate constipation, while types 4 and 5 are easy to pass stool.

Bristol Stool Chart™

Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	Type 7
Separate hard lumps, like nuts (hard to pass)	Sausage-shaped but lumpy	Like a sausage but with cracks on its surface	Like a sausage or snake, smooth and soft	Soft blobs with clear-cut edges (passed easily)	Fluffy pieces with ragged edges, a mushy stool	Watery, no solid piece, entirely liquid

Figure 3: Bristol Stool Chart™

Treatment of constipation

The two top priorities are:

1. **Maintaining or correcting adequate hydration status** (see 'Hydration' for more information). Of relevance, there is some research to suggest that adding electrolytes to beverages can be helpful in maintaining adequate stool output.
2. **Consuming adequate fiber per day.** It is recommended for athletes to consume 25-35 grams of fiber per day. While fiber is essential in the diet, excess fiber can also cause increased constipation risk, particularly in the setting of a slowed metabolism and gastroparesis.

It is important to provide the gut with adequate and consistent fuel for regular stool output, this includes having frequent meals that contain carbohydrates, protein, fat, and fiber. Constipation and increased intestinal transit time has been reported in those experiencing severe low energy availability, and in the context of eating disorders. If constipation becomes chronic, it is recommended that athletes work closely with a GI Doctor and sports dietitian prior to starting any over the counter regimens (e.g., osmotic laxatives, stool softeners, etc). Medication can be helpful, but it should not serve as the first line of defense when trying to resolve constipation.

Diarrhea

The evaluation of diarrhea can vary depending on sudden onset (duration), severity (how long it has been going on), and presence of additional symptoms. Treatment and course of action are dependent on the above. Acute diarrhea is >3 episodes of diarrhea for <14 days, while chronic diarrhea is when diarrhea lasts >14 days. Most research points to infection in acute cases of diarrhea.

'Runner's diarrhea' is characterized by frequent loose bowel movements during or immediately after a run. Research suggests that it is most likely caused by ischemic blood flow away from the gut. This can lead to decreased splanchnic blood flow, jostling of the intestines and abdominal contents during movement, as well as alterations to the small and large intestines, which can cause accelerated emptying.

Potential causes of acute loose stool/diarrhea in athletes

- Reduced gut blood flow during exercise
- Medications
- Carbohydrate malabsorption
- GI infections
- Various supplements
- Psychological stress/anxiety
- Ingestion of hypertonic fluids during exercise

Wilson (2020)

Treatment of diarrhea

Seeking treatment from a sports medicine team member or physician is recommended. Depending on longevity of diarrhea, other diseases such as Crohn's disease, Irritable Bowel Disease, Irritable Bowel Syndrome and Celiac disease should be ruled out.

Initially, seek GI Doctor support for:

- Total blood count
- Kidney function
- Sodium, potassium and magnesium (electrolytes)
- Stool sample: bacteria, parasites and if needed calprotecin
- Hydrogen breath test (for lactose intolerance)

For long term diarrhea, the following may be recommended:

- Celiac panel (Ttg IgA, IGg, EMA, GDP Iga and IGg)
- Ferritin, Vitamin D and B12
- SIBO breath test (hydrogen/methane)
- Further GI testing (e.g., colonoscopy)

Dietary recommendations

Short term loose stool/diarrhea	Dehydration is the first concern, therefore work on small sip rehydration with water and carbohydrate/electrolytes. If this is tolerated, slowly add food back into the diet. Recommend starting with low fat and low fiber.
Long term diarrhea	Reduce high fat and high fiber foods. Replenish fluid and electrolyes as best as possible. Make dietary changes slowly with support from a provider.
Diarrhea around exercise	Avoid beverages with high osmolality (> 500mOsm/L). Limit fiber, fat, and fructose around exercise.

Anxiety

Anxiety has been shown to cause short-term loose stool/diarrhea like symptoms in athletes. Anxiety may also be seen prior to, during, and after training and competition. Symptoms can be alleviated by an athlete making dietary changes, utilizing breathing techniques and/or receiving mental health support. Support from a sports dietitian can specifically aid athletes in hitting peak performance while dealing with symptoms.

Food intolerance

Food intolerance, also known as a food sensitivity, occurs when someone has difficulty digesting a particular food. Intolerances are regularly confused with food allergies, which involve the immune system.

Research has shown that 15-20% of the population have food sensitivities, with athletes shown to have a higher prevalence.

Potential symptoms of food intolerance

- Abdominal pain
- Loose stool and/or diarrhea
- Gas
- Bloating

Endurance athletes are identified to have more intolerances in comparison to other sports, possibly due to:

A lowered immune system (particularly in those with low energy availability)	Changes in food intake and thus changes to gut microbiota	High intensity exercise, which may decrease gastric motility and emptying

Diagnosing food intolerances

Utilizing diagnoses through a GI Doctor and/or GI Registered Dietitian is vital to understanding and discussing changes to an athlete's diet to support their training, as well as their gut health. IgG and IgE at home testing have not been shown to correctly identify intolerances or allergies. When trying to identify food allergies, it is recommended that athletes see an allergist for proper radioallergosorbent testing (RAST).

Irritable Bowel Syndrome (IBS)

There are three different subtypes of IBS, with bloating included in all three:

Diarrhea **Constipation** **Mixed**

There is a large mind-body connection in those struggling with IBS. Athletes can experience high levels of stress, which can make GI symptoms worse. When managing and treating IBS, everything that is happening within an athlete's life must be considered, i.e., factors both inside and outside of sport. Medication to support symptoms can only go so far, the athlete needs to be addressing their symptoms from multiple angles (e.g., nutritional, mental, stress management, self care, etc.)

Treatment of IBS

Research points to utilizing the elimination FODMAP diet to alleviate symptoms in those with IBS-diarrhea subtype. Alternatively, the FODMAP elimination diet has been shown to be restrictive and harder for athletes (e.g., when traveling on the road, or eating in a university dining hall), some research has shown that following the Mediterranean diet can be effective. Finally, research has shown that gut directed hypnotherapy (e.g., Nerva App) can aid in alleviating IBS symptoms. It can be completed in person, on the phone, or on a computer. Multiple studies have shown a decrease in symptoms like bloating, abdominal pain and stool symptoms with these directed breathing techniques.

It is important to be mindful of what season the athlete is in prior to starting a change in their dietary intake. This is because it could lead to an energy restriction, and thus possibly impact their performance. For example, when an athlete is in-season, food and symptom journals may be recommended, as opposed to starting the low FODMAP diet. This may help to identify 1-2 trigger foods to begin avoiding initially. More intensive dietary interventions are best left for the off-season or post-season, if possible.

Low FODMAP diet

The low FODMAP (fermentable oligosaccharides, disaccharides, monosaccharides and polyols) diet has been shown in some cases to be beneficial when looking at intolerances in athletes. It is a big misconception among athletes that the FODMAP diet is a long-term lifestyle change, however it is meant to be used as a temporary elimination (no longer than 4-6 weeks, in most cases), followed by a systematic reintroduction period to identify what foods the body does not tolerate. Long term use of the low FODMAP diet has been shown to cause adverse reactions in gut microbiota. A dietitian should support an athlete in finding which foods could be causing GI symptoms, and when it is appropriate to implement a low FODMAP diet. It is not recommended to be utilized as a tool in athletes with eating disorders.

Probiotics and gut health

The use of probiotics in sports has been rapidly growing over the past few years, focusing on both GI symptoms and upper respiratory tract symptoms commonly seen in athletes. Athletes embark on long travel trips and experience exhaustive training loads, lack of sleep, and sometimes poor nutrition due to the demands of sport. These stressors on an athlete's body can lead to immunosuppression, oxidative stress, increased upper respiratory illness (URS), and GI disorders. Approximately 70% of antibody producing cells are located in the digestive system, meaning if the gut is compromised, the body's ability to fight off infection can be compromised.

Considerations

When assessing an athlete with GI symptoms, dietary interventions and a clinical work up should always serve as the first line of defense, and probiotic supplementation can be one potential strategy to consider. There is some evidence to indicate that probiotics can be effective and safe for both preventing and treating GI complaints, but athletes responses to probiotic interventions are very individualized. It is not a 'one size fits all' approach.

There is a large variety of probiotics available, with different doses, strains or multi strains, prebiotics added, third party testing etc. Unfortunately, symptoms may be exacerbated in some cases, particularly if there are prebiotics added and the athlete has an underlying GI condition. When selecting a probiotic, it is important to select one supportive of GI symptoms or general health. The majority of research has been conducted in male athletes, and therefore the findings may not be applicable to female athletes. Nevertheless, research does seem to show that Lactobacillus, Bifidobacterium, Enterococcus, Bacillus and Streptococcus support positive changes in athletes. They aid in reduction of fatigue and exertion, especially seen with heterogeneity of strains vs. single strain. In regard to GI health, it is recommended to work on utilizing a probiotic to support gut symptoms. For instance, many studies have shown that use of the probiotic VSL#3 can aid in diarrhea. It is always recommended that prior to starting a probiotic supplement, an athlete meets with a Registered Dietitian.

Top tips for minimizing GI symptoms in athletes

- Encourage athletes to practice fueling strategies prior to competition, ensuring to experiment with pre-, during and post-exercise nutrition strategies many times before the day of a competition.
- Athletes should avoid high-fiber foods during the days leading up to competition, and on competition day. Fiber is essential to maintain bowel regularity, however around high intensity and/or long duration exercise, it can cause GI distress.
- Athletes should avoid the overuse of aspirin and NSAIDs, such as ibuprofen. Both aspirin and NSAIDs have commonly been shown to increase intestinal permeability and may increase the incidence of GI complaints.
- Athletes should avoid high fructose containing foods around exercise, for example fruit juices. It is recommended to utilize products/foods that have sources of both fructose and glucose to minimize risk of GI complaints.
- Athletes should maintain good hydration status, as dehydration can exacerbate GI symptoms. Educate athletes on the importance of arriving at training, competition or a race well hydrated.
- Athletes should work with a sports dietitian to help create a fueling plan that works best for them individually.

Checklist for helping an athlete with GI symptoms

☐ Food and symptom journal

Ask the athlete to:

- Log everything that they consume for 2 week days and both weekend days (including the timing of consumption). Includes foods, fluids, medications, supplements, and caffeine..
- Includes and the timing of; foods, fluids, medications, supplements, and caffeine.
- Log their GI symptoms (bloating, gas, diarrhea, belching, etc.) as they present; where on the body it occurs, and bowel movements using the Bristol Stool Chart™.
- Log training times and duration.

☐ What diet changes can be made to alleviate some symptoms?

- Change the timing of meals and snacks around training?
- Alter the composition of meals and snacks at different points of the day?

☐ Would a probiotic be helpful?

☐ Is the athlete taking any over the counter medications or supplements?

☐ Could it potentially be REDs, an eating disorder, or disordered eating?

☐ How high are the athletes stress levels?

- Mental health provider referral?
- Nerva App

☐ Would a consult with a GI physician be helpful?

- Lab tests/stool sample

GUT HEALTH

30-90% of athletes suffer from gastrointestinal (GI) symptoms	Female athletes report greater prevalence of GI symptoms at rest, but not during exercise, compared to male athletes	Female athletes report greater incidences of GI complaints during menstruation

Common upper and lower exercise-induced GI symptoms

Upper abdominal symptoms

- Reflux/heartburn
- Belching
- Bloating
- Stomach pain/cramps
- Vomiting
- Nausea

Lower abdominal symptoms

- Intestinal/lower abdominal cramps
- Flatulence
- Diarrhea
- Urge to defecate (urgency)

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