## Micronutrient application

Not all foods are created equal with regard to the availability of the nutrients contained within them. The availability of a nutrient for assimilation into the body from food is known as bioavailability. Bioavailability is defined as the fraction of the ingested nutrient that is absorbed and subsequently utilized for normal physiological functions (Fairweather-Tait & Hurrell, 1996).

Some foods make digestion and absorption of micronutrients easier than others. There are some key aspects that impact the bioavailability of a nutrient: solubility, the type of micronutrient, how it is bound up in the food, and the co-ingestion of other foods or compounds that facilitate absorption or compete with it. The bioavailability of each micronutrient appears to be affected by different factors and uniform rules do not appear to apply to each micronutrient or ever-larger classes of nutrients (Infographic: Bioavailability).

A close-up of a brochure

AI-generated content may be incorrect.

For example, the bioavailability of fat-soluble vitamins is greatly impacted by what they are consumed with. When consumed with dietary fat, their bioavailability is much higher than when consumed without fat. Conversely, the bioavailability of iron is impacted by the form of iron consumed. However, there are some factors that tend to make some micronutrients more or less bioavailable: the food source, co-ingestion with other foods/molecules, and what form the micronutrient is in or is bound to.

**Iron**

Iron can be used as a use case to highlight some of the factors that influence bioavailability. The source and form of a micronutrient impacts its bioavailability: both where it is from and what form it is found. For example, heme iron, which is found in animal sources, is absorbed more efficiently (10 to 35% absorption) when compared to nonheme iron (2 to 20% absorption), which is found in plants (Monsen, 1988[)](https://paperpile.com/c/cZDv7y/PtFL8). Even among those broader categories, there are substantially different rates of absorption. For example, in heme iron sources, about 10% of iron is absorbed from fish, while 20% is absorbed from veal muscle. In non-heme sources, roughly 2% of iron is absorbed from black beans, while 7% is absorbed from soybeans (Layrisse et al., 1969).

Absorption of iron can be enhanced by co-ingestion of vitamin C, especially non-heme iron. Conversely, absorption of iron is substantially reduced when co-ingested with phytates, which are often found in whole-grain foods such as bran (Hallberg, 1987[)](https://paperpile.com/c/cZDv7y/dlzot). While this example highlights many of the factors affecting bioavailability, it is important to note that these exact factors do not affect all foods in the same way. What impacts the bioavailability of each micronutrient needs to be assessed on a nutrient-by-nutrient level.

### Total daily requirements

The daily requirement for each micronutrient is explained by several different reference amounts that fall under the umbrella of dietary reference intakes (DRI) (Table: Reference Intake Descriptions).

Reference Intake Descriptions

| **Dietary Reference Intake Label** | **Description** |
| --- | --- |
| Estimated Average Requirement (EAR) | A nutrient intake value that is estimated to meet the requirement of half the healthy individuals in a group |
| Recommended Dietary Allowance (RDA) | The average daily dietary intake level that is sufficient to meet the nutrient requirement of nearly all (97 to 98%) healthy individuals in a group |
| Adequate Intake (AI) | A value based on observed or experimentally determined approximations of nutrient intake by a group (or groups) of healthy people – used when an RDA cannot be determined |
| Tolerable Upper Intake Level (UL) | The highest level of daily nutrient intake that is likely to pose no risk of adverse health effects to almost all individuals in the general population – As intake increases above the UL, the risk of adverse effects increases. |

Getting Technical

There is a systematic process for how each of these reference values are defined. The EAR is determined through a systematic review of the literature and uses human data and animal data to help determine an accurate EAR. The RDA is then calculated by using either two standard deviations or coefficient of variation for the EAR of 10%, which is ordinarily assumed. The AI is set when there is not enough evidence in the scientific literature to establish an EAR and is often limited to specific groups of people in which there is evidence.

[**Daily reference intakes in the general population**](http://nasmu.nasm.org/file.php/10359/pdf/Chapter_10/RDA_for_Micronutrient_Handout.pdf)

Research collated over the past several decades has illuminated RDAs for the major micronutrients present in the human diet for the general population. See Handout: Micronutrient RDA for a complete list of RDAs for the vitamins and minerals discussed and to help support your discussions with clients (“Office of Dietary Supplements - Nutrient Recommendations: Dietary Reference Intakes (DRI),” n.d.).

Critical!

It is important to remember that RDA numbers are set on normative population data and that individuals have differing requirements. These are to be used as broad guidelines and some populations may have different requirements. For example, people who are located in higher latitudes require more vitamin D from their diet than people who live closer to the equator. Do female athletes, on average, require more iron relative to their calorie intake than males? Each client is unique and has their own unique needs; however, making individual recommendations is tricky and should be done by a registered dietitian nutritionist.

[**The effect of physical activity on daily recommended Intakes**](http://nasmu.nasm.org/file.php/10359/pdf/Chapter_10/Effects_of_Physical_Activity_on_DRI_of_Micronutrients_Handout.pdf)

There are additional considerations when determining DRIs for people who undertake higher levels of physical activity: increased energy demands, larger muscle mass, increased loss of solutes due to excessive sweating, and so on. It seems clear that athletes are likely to have different daily requirements for micronutrients than non-athletic populations; however, there are some substantial limitations that prevent the development of guidelines for athletes. Namely, small sample sizes, vastly different energy requirements and micronutrient utilization, different perspiration rates and overall volume of fluid and micronutrients loss due to perspiration, and so on. As such, there is currently not enough literature basis to establish separate and individual DRIs (EAR, RDA, AI, and UL) for athletic populations.

There has not been a systematic evaluation of the literature that examines the effect of physical activity on micronutrient needs. Most evidence is in the form of examining higher-dose supplementation in micronutrient deficient athletes, which precludes us from drawing conclusions about setting distinct DRI values for highly active people; however, there is some data available that can help guide some decisions. One of the most studied micronutrients impacted by physical activity is iron. In this example, the evidence suggests that highly active people, especially long-distance runners, have an about 70% increased requirement for iron intake when compared to non-runners (Whiting & Barabash, 2006).

Use Handout: Effects of Physical Activity on Micronutrient DRI to help support the discussions you have with your clients.

Food For Thought

A lack of systematic investigations into an increased micronutrient demand in athletes does not mean the problem is nonexistent. More research is required on this topic. Individualized nutrition is a critical part to successful dietary management in athletes, part of which requires understanding micronutrient status.

### Micronutrient programming

The vast range of micronutrients, their roles in the human body, and the varying levels of requirements can make dietary recommendations for meeting micronutrient needs appear complex and daunting. However, in practice, addressing micronutrient needs can be achieved using simple approaches. This is due, in large part, to the body's regulatory mechanisms for helping clear excess nutrients, regulating absorption, and having wide ranges between meeting daily minimum requirements and upper limits of intake. Furthermore, micronutrients are present in most of the available and commonly consumed foods. This section will discuss how to apply the knowledge learned in this module to your clients and supporting their nutritional needs.

**Covering the food spectrum**

There is no singular diet or approach to eating required to achieve complete macro- and micronutrition. The human diet has evolved over millennia, continents, and myriad cultural and technological revolutions, resulting in a breadth of different dietary approaches, many of which meet modern-day nutrition guidelines. As stated by the Food and Agricultural Organization of the United Nations (2002),

Advice for a healthy diet should provide both a quantitative and qualitative description of the diet for it to be understood by individuals, who should be given information on both size and number of servings per day.

The quantitative aspects include the estimation of the amount of nutrients in foods and their bio-availability in the form they are actually consumed. The qualitative aspects relate to the biologic utilization of nutrients in the food as consumed by humans and explore the potential for interaction among nutrients.

Pragmatically speaking, achieving complete macro- and micronutrition in the developed world is best achieved by eating a well-balanced diet: several servings of fruits and vegetables, whole grains, and lean meats or fish (Table: Micronutrient Sufficient Diet Example).

This approach to eating provides adequate micronutrition for the water- and fat-soluble vitamins, along with adequate mineral micronutrition. An example of the macro- and micronutrient breakdown of this dietary pattern can be seen below.

Micronutrient Sufficient Diet Example

|  |
| --- |
| Example: 2,000 kcal per day diet following USDA guidelines for meeting micronutrient needs |
| * 4 servings of fruit per day * 2.5 cups of vegetables per day, comprising of the following:   + 3 cups of dark green vegetables per week   + 2 cups of orange vegetables per week   + 3 cups of legumes (dry beans) per week   + 3 cups of starchy vegetables per week   + 6.5 cups of other vegetables per week * 3 ounces of whole grains and 3 ounces of other grains per day * 5.5 ounces of meats, poultry, or fish per day * 3 cups of dairy (milk, cheese, or yogurt) per day * 6 teaspoons of oils per day |

In order to easily achieve complete micronutrition, it is best to avoid diets that utilize severe restriction of macronutrients (e.g., very-low-carb diets), omit entire food groups (e.g., vegan diets or the keto diet), or eat very-low energy for extended periods of time. Further, these specific protocols, or any others, should be discussed with a RDN and supported by a Nutrition Coach. While there are special considerations for unique populations, the moderate, balanced approach achieves complete macro- and micronutrition for greater than 90% of the population.

Macro- and Micronutrient Breakdown

| **Example: 2,000 kcal per day diet following USDA guidelines for meeting micronutrient needs** | |
| --- | --- |
| **Nutrient** | **USDA Food Guide (2,000 kcals)** |
| Protein, g | 91 |
| Carbohydrate, g | 271 |
| Total fat, g | 65 |
| Saturated fat, g | 17 |
| Monounsaturated fat, g | 24 |
| Polyunsaturated fat, g | 20 |
| Potassium, mg | 4,044 |
| Sodium, mg | 1,779 |
| Calcium, mg | 1,316 |
| Magnesium, mg | 380 |
| Copper, mg | 1.5 |
| Iron, mg | 18 |
| Phosphorus, mg | 1,740 |
| Zinc, mg | 14 |
| Vitamin B1, mg | 2 |
| Vitamin B2, mg | 2.8 |
| Vitamin B3, mg | 22 |
| Vitamin B6, mg | 2.4 |
| Vitamin B12, μg | 8.3 |
| Vitamin C, mg | 155 |
| Vitimain E (AT)g | 9.5 |
| Vitamin A, μg (RAE)h | 1,052 |

### Supplementation

Supplementation of vitamins and minerals should be viewed as supplements to an otherwise healthy and/or robust diet. For the most part, much of a person’s micronutrient needs (including athletes) can be met through a diet that is rich in fruits, vegetables, grains, and some animal products or animal by-products. Thus, even in societies where dietary quality may appear to be poor or with a chronic disease driven by excess consumption, these dietary patterns do appear to largely meet micronutrient levels in a robust manner.

Critical!

This type of dietary pattern is achieved quite readily by developed countries (including the United States) with deficiencies in micronutrients ranging from less than 1% for folate, vitamin E, and vitamin A, to about 10% for vitamin B6 (Centers for Disease Control and Prevention, 2014).

A recent study examining the behavior patterns of individuals who take supplements compared to those who do not found that, on average, individuals who do take supplements tend to have a 1 kg/m2 lower BMI and an overall healthier diet than people who do not consume supplements (Anders & Schroeter, 2017).

This data seems to suggest that, for most people who consume supplements, dietary supplements are likely to be function of nutrient support and not as placeholders for an otherwise nutrient-dense diet. While the general population should rely primarily on food sources for micronutrients, there are some populations in which supplementation ought to be considered in addition to a food-based diet as a standard approach. For example:

1. Aging and/or institutionalized populations benefit from vitamin D and/or calcium supplementation (Krieg et al., 1999; Meehan, 2014[)](https://paperpile.com/c/cZDv7y/ESIgz+RIjPa).
2. Individuals with celiac disease benefit from additional folate, vitamin B12, vitamin D, and calcium supplementation [(Caruso, Pallone, Stasi, Romeo, & Monteleone, 2013)](https://paperpile.com/c/cZDv7y/P6OMq), and pediatric patients with intractable epilepsy benefit when placed on a ketogenic diet (Lee, Kang, & Kim, 2016).

Again though, it is an important reminder that any diet or supplementation recommendation legally needs to come from a RDN.

**Multivitamin / Mineral vs. individual nutrients**

There are both advantages and disadvantages to taking individual nutrients as a supplement when compared to a multivitamin. Using single nutrients can impart the ability to target and correct single nutrient deficiencies quicker and more effectively. For example, an individual can correct a vitamin D deficiency much faster supplementing with higher doses of vitamin D (e.g., 1000 IU per day) than if they were consuming vitamin D at lower doses (e.g., 100 IU per day) as part of a multivitamin. Controlling the exact type, source, and dosage, is easier when using individual nutrient supplements.

**People restricting energy & other populations of concern for deficiencies**

Micronutrition often becomes compromised during periods of overall energy restriction, or in diets that restrict specific food groups or have very strict rules surrounding food choices. Long periods of caloric restriction or substantial weight loss also place people at risk for developing micronutrient deficiencies. Long periods of overall caloric restriction typically lead to less micronutrition as less overall food is being consumed. Despite the decreased intake in micronutrients from less food, the body is still using a high level of energy and requires the same amount of micronutrition.

In one study, participants who were obese with suboptimal levels of micronutrition saw further decreases in micronutrient status during a 3-month period of caloric restriction and weight loss (Damms-Machado, Weser, & Bischoff, 2013). This decrease occurred despite consuming a protein-rich formula diet containing vitamins and minerals that were designed to cover the DRI.

Coach's Corner

Micronutrient deficiencies are observed in many popular diets. For example, one study that examined micronutrient status in people following the Atkins Diet, the South Beach Diet, the Best Life Diet, and the DASH Diet found that all four diets led to nutrient deficiencies in one or more micronutrients [(Calton, 2010)](https://paperpile.com/c/cZDv7y/NQicV). The deficiencies were quite large in each diet.

The Atkins Diet was only 44% sufficient, meeting only 12 out of 27 essential micronutrients, while the Best Life Diet was 56% (15 out of 27), the DASH Dietwas 52% (14 out of 27), and the South Beach Diet was 22% sufficient (6 out of 27). Similar findings were observed in a study examining a commercial vegan diet (Eat to Live-Vegan, Aggressive Weight Loss) as well as a commercial high-animal protein, low-carbohydrate diet (Engel, Kern, Brenna, & Mitmesser, 2018[)](https://paperpile.com/c/cZDv7y/PmTqx).

There is also some concern for nutrient deficiencies among people with celiac disease. Those with celiac disease must restrict gluten-containing foods in their diet. Further, because of the nature of the disease, which affects digestion and absorption in the intestine, it can also have a negative effect on nutrient transport and absorption. In a study of newly diagnosed people with celiac disease, 87% of people had at least one nutrient that was considered deficient; 7.5% were deficient in vitamin A, 20% in vitamin B12, 67% in zinc, and roughly 46% showed decreased iron storage (van der Schueren, Berkenpas, Mulder, & van Bodegraven, 2013).

It has been argued that on removal of gluten and the healing of the villi, which restores nutrient uptake capacity, many of these deficiencies can be restored; however, supplementation of folate, vitamin B12, vitamin D, and calcium is recommended as these levels do not always get restored and restoration to normal may not be enough to address reductions in bone density that occur during the disease [(](https://paperpile.com/c/cZDv7y/P6OMq)Caruso et al., 2013). These unique dietary challenges make it even more important to collaborate with an RDN, as working with clients who have unique health situations is outside the scope of a Nutrition Coach.

Vitamins and minerals are essential nutrients the body relies on to sustain life, prevent disease, and promote overall health and well-being. The amount of micronutrients needed to optimize the former are small in comparison to its predecessor, macronutrients. Sufficient quantities can be obtained through a balanced diet that contains fruits, vegetables, nuts or seeds, animal meat, dairy, and shellfish. This includes achieving sufficient micronutrient status for the fat- and water-soluble vitamins as well as minerals.

Achieving sufficient micronutrient status can be accomplished by following basic guidelines based on the best-known available literature and current dietary recommendations from various governing bodies around the world. See Table: Micronutrient Sufficient Diet Example for an example of a typical diet that meets these guidelines.

Micronutrient Sufficient Diet Example

|  |
| --- |
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| * 4 servings of fruit per day * 2.5 cups of vegetables per day, comprised of the following:   + 3 cups of dark, green vegetables per week   + 2 cups of orange vegetables per week   + 3 cups of legumes (dry beans) per week   + 3 cups of starchy vegetables per week   + 6.5 cups of other vegetables per week * 3 ounces of whole grains and 3 ounces of other grains per day * 5.5 ounces of meats, poultry, or fish per day * 3 cups of dairy (milk, cheese, or yogurt) per day * 6 teaspoons of oils per day |

In addition to these dietary guidelines, supplementation is often viewed as an insurance policy for a diet that may not meet all of the recommendations or in special populations who suffer from nutrient deficiencies, such as in lower socio-economic countries or with individuals located at northern latitudes. Supplementation should be a targeted intervention that is utilized after a proper assessment of nutrient status is conducted. It should be used in addition to improving overall dietary habits and the inclusion of micronutrient rich foods. It should only be recommended by a RDN or an individual’s physician.

Currently, there is little evidence (outside of correcting nutrient deficiencies) that micronutrient supplementation increases athletic performance. Thus, taken together, it is understood that micronutrients are complex and essential for biochemical, physiological, and structural alterations that contribute to health and performance. However, evidence lacks in ergogenic effects outside of disease and deficiencies.

In this chapter, you learned about:

* The role of and importance of water-soluble vitamins.
* The role and importance of fat-soluble vitamins.
* Minerals required for daily function and optimal health.
* Micronutrient application.