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Nutrition for Endurance Athletes

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What is sports Nutrition?

- Sports nutrition involves the application of nutritional principles to enhance athletic performance
- Sports nutrition is the application of eating strategies with several major objectives (Louise Burke)
  - promote good health
  - promote adaptations to training
  - recover quickly after each training session
  - perform optimally during competition

What is sports Nutrition?

- Sports nutritionists may meet these objectives in various ways
  - developing meal plans for training, recovery, and competition
  - providing appropriate information about healthy diets
  - discussing the efficacy, safety, and permissibility of sports supplements
  - counseling individual athletes with special diets, such as vegetarians
  - monitoring athletes for weight loss and eating disorders

What is sports Nutrition?

- The nutrients in the foods we eat can affect exercise and sports performance in accordance with the three major functions of nutrients
  - nutrients may provide energy for the different energy-producing systems
  - nutrients also help regulate metabolic processes important to energy production and temperature regulation during exercise

What is sports Nutrition?

- The nutrients in the foods we eat can affect exercise and sports performance in accordance with the three major functions of nutrients
  - nutrients support the growth and development of specific body tissues and organs as they adapt to exercise training
- A well-planned, sport-specific diet will help optimize sports performance, but a poor diet plan may lead to impaired performance

The Different Types of Athletes

- Short-duration, high-intensity sport athletes
- High-intensity, intermittent sport athletes
- Endurance and ultra-endurance sport athletes

Short-Duration, Very High and High-Intensity Sport Athletes

- Short-duration, very high-intensity sports require all-out effort or near-maximal effort, and last less than 30 seconds
- Short-duration, high-intensity sports require near-maximal effort and can last several minutes

Short-Duration, Very High and High-Intensity Sport Athletes

- This includes:
  - sprints (run, cycle, swim, skate)
  - middle-distance events (running, rowing)
  - jumping or throwing events (field)
  - single moves or plays during a game (football, basketball, baseball, soccer)
  - olympic and power weightlifting

High-Intensity, Intermittent Sport Athletes

- Activities that require short periods of all-out effort (sprinting), followed by periods of less-intense effort (jogging) and low-intensity effort (walking)
- These sports include team sports
  - soccer
  - football
  - basketball
  - lacrosse
  - field hockey
  - ice hockey
  - rugby
  - volleyball

Endurance and Ultra-Endurance Athletes

- Endurance athlete – an athlete who participates in sports involving continuous activity (30 minutes to four hours) involving large muscle groups
- Ultra-endurance athlete – a subgroup of endurance athletes who engage in extremely long bouts of continuous activity lasting 4-24 hours

Endurance and Ultra-Endurance Athletes

- Endurance sports include:
  - half marathon and marathon runs
  - olympic distance triathlons
  - cross-country skiing
  - obstacle course races
  - road and mountain cycling events

Endurance and Ultra-Endurance Athletes

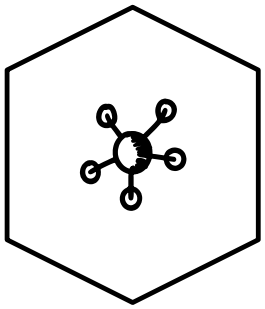
- Ultra-endurance sports include multistage or multiday ultra-endurance events over consecutive days like the Tour de France, Ironman triathlons, and ultra-marathons

What is different about endurance athletes?

- All athletes
  - use and need fuel for energy to train/compete
  - sweat and need hydration
  - use muscles and need strength
- Endurance athletes
  - train and compete for long durations (low-moderate intensity exercise)
  - steady state vs. intermittent high-intensity exercise
  - sport-specific: runners, cyclists, or triathletes

ENERGY

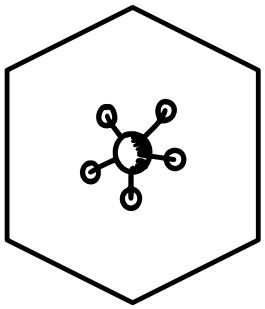
HYDRATION, VITAMINS & MINERALS



STRUCTURE

ENERGY

HYDRATION, VITAMINS & MINERALS



STRUCTURE

Energy – Calories

- A calorie is a unit of measure of energy or heat
- The definition of a calorie is the amount of heat energy it takes to raise the temperature of 1 liter of water 1º Celsius
- Calorie needs vary among athletes and are based on body size, body composition, and type of training

Energy – Calories

- The Harris-Benedict formula can be used to estimate calorie needs in athletes
  - for men: basal metabolic rate (BMR) = 10 x weight (kg) + 6.25 x height (cm) – 5 x age (years) + 5
  - for women: BMR = 10 x weight (kg) + 6.25 x height (cm) – 5 x age (years) – 161

Energy – Calories

- The Harris-Benedict formula can be used to estimate calorie needs in athletes
  - sedentary (little or no exercise): calorie-calculation = BMR x 1.2
  - lightly active (light exercise/sports 1-3 days/week): BMR x 1.375
  - moderately active (moderate exercise/sports 3-5 days/week): BMR x 1.55
  - very active (hard exercise/sports 6-7 days a week): BMR x 1.725
  - extra active (very hard exercise/sports and a physical job): BMR x 1.9

Energy

- The biologically usable form of energy in the body is adenosine triphosphate (ATP)
- ATP is a complex molecule constructed with high-energy bonds, which, when split by enzyme action, can release energy rapidly for a number of body processes, including muscle contraction
- ATP is classified as a high-energy compound and is stored in the tissues in small amounts

Energy

- ATP is the immediate source of energy for all body functions, and the other energy stores are used to replenish ATP at varying rates
- Muscle contraction is totally dependent on ATP, so the body has developed an intricate system to help replenish ATP as rapidly as needed

The Energy Systems

- Adenosine triphosphate-phosphocreatine (PCr) system
- Anaerobic glycolysis
- Aerobic metabolism

Adenosine Triphosphate-Phosphocreatine System

- The most rapid method that the body uses to produce ATP (is very limited and can only supply energy for up to 10 seconds)
- Although it cannot be used as an immediate source of energy, it can rapidly replenish ATP
- The ATP-PCr system is also known as the phosphagen system because both ATP and PCr contain phosphates

Adenosine Triphosphate-Phosphocreatine System

- The main purpose of every other energy system, including PCr, is to help regenerate ATP to enable muscle contraction to continue at the optimal desired rate

Anaerobic Glycolysis

- The anerobic glycolysis, or lactic acid system, cannot be used directly as a source of energy for muscular contraction, but it can help replace ATP rapidly when necessary
- If you are exercising at a high intensity level and need to replenish ATP rapidly, the next best source of energy besides PCr is glucose

Anaerobic Glycolysis

- Glucose may enter the muscle from the bloodstream or may be derived from the breakdown of glycogen stored in the muscle
- The glucose molecule undergoes a series of reactions to eventually form ATP, a process called glycolysis – it is used in sports events in which energy production is near maximal for 30-120 seconds, such as a 200 or 800 meter run

Anaerobic Glycolysis

- Anaerobic capacity is a term often associated with the lactic acid energy system
- Muscle glycogen and glucose can break down without the utilization of oxygen – this process is called anaerobic glycolysis

Anaerobic Glycolysis

- ATP is produced rapidly, but lactic acid is the end product; lactic acid may be a major cause of fatigue in the muscle
- The lactic acid energy system is utilized primarily during exercise bouts of very high intensity, those conducted at maximal rates for about 30-120 seconds

Aerobic Metabolism

- Aerobics was a term used by Dr. Kenneth Cooper in 1968 to describe a system of exercising that created an exercise revolution in this country – in essence, aerobic exercises are designed to stress the oxygen system and provide benefits for the heart and lungs

Aerobic Metabolism

- The oxygen system, like the lactic acid system, cannot be used directly as a source of energy for muscle contraction, but it does produce ATP in rather large quantities from other energy sources in the body

Aerobic Metabolism

- Muscle glycogen, liver glycogen, blood glucose, muscle triglycerides, adipose cell triglycerides, and body protein all may be ultimate sources of energy for ATP production and subsequent muscle contraction – to do this, glycogen, fats, and protein must be present within the muscle cell or must enter the muscle cell

Aerobic Metabolism

- Through a complex series of reactions, metabolic by-products of carbohydrate, fat, or protein combine with oxygen to produce energy, carbon dioxide, and water – at different steps in this process, energy is released and ATP is formed

Aerobic Metabolism

- Although the rate of ATP production is lower, the major advantage of the oxygen system over the other two energy systems is the production of large amounts of energy in the form of ATP
- This process may be adequate to handle mild and moderate levels of exercise but may not be able to meet the demand of very strenuous exercise

Aerobic Metabolism

- The oxygen system is used primarily in sports emphasizing endurance, such as distance runs ranging from a 5 K (3.1 miles) to the 26.2-mile marathon and beyond

Endurance Energy System

- Primary energy system used during endurance exercise is the aerobic system
  - aerobic power – the rate of aerobic ATP production
  - usually represented by the fastest pace or rate of physical activity an athlete can sustain (is an indicator of cardiorespiratory fitness)

Energy Requirements

- Energy needs vary for endurance athletes depending on their exercise intensity, duration, mode, and environmental conditions
- A main concern for endurance athletes is matching energy consumption with energy expenditure – if the calories an athlete burns are not replaced daily, energy for training and performing during competitions will decline

Average Energy Needs For Non-Athletes

TYPE OF PERSON	ENERGY INTAKE
Male (128 lb, age 19-24)	1,780 kcal/day
Male (138 lb, age 25-50)	1,800 kcal/day
Male (143 lb, age 51+)	1,530 kcal/day
Female (128 lb, age 19-24)	1,350 kcal/day
Female (138 lb, age 25-50)	1,380 kcal/day
Female (143 lb, age 51+)	1,280 kcal/day

https://www.ncbi.nlm.nih.gov/books/NBK234938/table/ttt00007/?report=objectonly

Energy Requirements

TYPE OF ATHLETE	ENERGY INTAKE FOR TRAINING
Male elite ultra-endurance athlete	4,079 kcal/day
Male marathon runners	3,570 kcal/day
Male elite distance runners	3,478 kcal/day
Male elite road cyclists	5,333 kcal/day
Female elite road cyclists	3,261 kcal/day
Female adventure racer	3,272 kcal/day (based on 150 lb woman)

Macronutrient Breakdown

- Carbohydrate: 5-12 g/kg body weight
- Protein: 1.2-2.0 g/kg body weight
- Fat: 20-35% of total energy intake
- These ranges all depend on an athlete's specific training needs, total energy intake, and training performance

Carbohydrates (CHO) are the primary fuel for muscle contraction

Carbohydrates

- Carbohydrate are made of building blocks of sugar and include classes:
  - monosaccharides
  - disaccharides
  - oligosaccharides
  - polyols
  - starch polysaccharides
  - non-starch polysaccharides

Carbohydrates

- Functions of carbohydrates in the body
  - direct source of energy for the muscles, brain, and other cells
  - energy storage
  - spare protein and fat for other uses
  - structure of cells, tissues, and organs

Sources of Carbohydrates

- Wheat, rice, and oat products
- Pasta, noodles, crackers, and flour tortillas
- Cornmeal and popcorn
- Milk and milk products
- Beans and peas
- Fruits
- Starchy vegetables (potatoes, corn)

Carbohydrates are Limited in the Body

- Carbohydrates are stored in the liver and muscles
  - there is limited storage capacity for carbohydrate
  - the body relies primarily on carbohydrates during higher intensity exercise
  - eating carbohydrates helps replenish glycogen stores

What is Glycogen?

- A starch – long chain of glucose molecules and the storage form of glucose in cells
- Muscle glycogen is a major energy source for muscle contraction, and is only used by the muscle
- Liver glycogen helps maintain blood glucose, which can be used by the brain and muscles during exercise
- Glycogen stores are often a limiting factor for endurance performance – once stores are low, the athlete will fatigue quickly, "hitting the wall"

Carbohydrates

- Adequate carbohydrate intake is crucial for endurance athletes
  - carbohydrates are needed to make glycogen
  - fatigue during endurance exercise is often associated with muscle glycogen depletion
  - nutritional strategies to ensure carbohydrate availability before, during, and after exercise are vital for performance

Daily CHO Intake – Endurance Athlete

- 6-10 g/kg/day – moderate training
- 8-12 g/kg/day – heavy training
- Fatigue in an endurance athlete is often due to depleted muscle glycogen and low levels of blood glucose

CHO Daily Intake Example

- Endurance athlete
  - John is training for a triathlon and wants to know how much daily CHO he should be consuming. He weighs 86 kg and has moderate and heavy training days.
  - How much daily CHO should he consume?
    - 6-10 g/kg/day – moderate training
    - 8-12 g/kg/day – heavy training

CHO Daily Intake Example

- **Endurance athlete**
  - **John is training for a triathlon and wants to know how much daily CHO he should be consuming. He weighs 86 kg and has moderate and heavy training days.**
  - **How much daily CHO should he consume?**
    - **Moderate: 6 g of CHO * 86 kg = 516 g of CHO/day or 10 g of CHO * 86 kg = 860 g of CHO/day (516-860 g of CHO per day)**
    - **Heavy: 8 g of CHO * 86 kg = 688 g of CHO/day or 1,032 g of CHO/day (688-1032 g of CHO per day)**

Carbohydrates ***before*** training or event

CHO Before Training & Competition

- 1-4 hours prior to exercise
  - the athlete should consume 1-4 g of CHO/kg of body weight
  - the choice of where within this range an athlete falls depends on a number of factors, including the type of sport/event, goal of the athlete, stomach issues, practice time, and when coach plans pre-game meals

CHO Before Training & Competition

- 1-4 hours prior to exercise
  - carbohydrates could be consumed in any of several forms, including fluids such as juices or glucose polymer solutions, or solid carbohydrates, such as fruits or starches
  - fiber content should be minimized to prevent possible intestinal problems during exercise

CHO Before Training & Competition

- <1 hour prior to exercise
  - the amount and type of CHO consumed is based on the athlete's preference and tolerance
  - intake in this window begins to meet the "during" exercise needs of the athlete

CHO Before Training & Competition

- <1 hour prior to exercise
  - many athletes do well with 25-30 g of CHO during this time period which is an appropriate amount when considering during exercise recommendations
  - consuming CHO during this time period is particularly important if the athlete cannot or will not consume fuel during their training or competition

CHO Before Training & Competition: Type

- Athletes should choose carbohydrate-rich foods with minimal fiber, fat, and protein
  - fiber, fat, and protein can slow the digestion and absorption process
  - if consumed too close to the start of exercise, these nutrients can potentially cause gastrointestinal distress during exercise

CHO Before Training & Competition: Type

- All athletes should practice pre-exercise nutrition strategies to find the best timing and amount that will work for them during competition

CHO Before Training & Competition

- Three hours before a marathon
  - Sheila is training for a marathon and practicing her pre-race breakfast before her 20-mile training runs. She weighs 75 kg and tolerates CHO well.

CHO Before Training & Competition

- Three hours before a marathon
  - She plans to eat breakfast about three hours before her marathon. Within this window, she should aim for 3-4 g/kg, and then adjust as needed.
    - 3 g CHO * 75 kg = 225 g CHO
    - 4 g CHO * 75 kg = 300 g CHO
    - good food choices: bagel, pancake, fruit, toast with peanut butter, oatmeal (if she can tolerate the fiber), cereal

Carbohydrates *during* training or event

CARBOHYDRATES IMPROVE ENDURANCE PERFORMANCE

- Consuming carbohydrate during exercise results in:
  - maintenance of blood glucose levels
  - maintenance of performance levels

Coyle EF, Coggan AR, Hemmert MK et al., *J Appl Physiol.* 1986;61(1):165-172

Carbohydrate Loading

- Carbohydrate loading can improve performance in endurance events longer than 90 minutes – 2-3 days of high carbohydrate intake (10-12 g/kg)
- A high carbohydrate meal consumed 1-4 hours before exercise can help by "topping off" liver and glycogen stores (pre-exercise meal should contain 1-4 g carbohydrate per kilogram of body weight)

Carbohydrate Loading

- Carbohydrate loading is primarily suited for individuals who will sustain high levels of continuous energy expenditure for prolonged periods, such as long-distance runners, swimmers, bicyclists, triathletes, cross-country skiers, and similar athletes

Carbohydrate Loading

- In addition, athletes who are involved in prolonged stop-and-go activities, such as soccer, lacrosse, and tournament-play sports like tennis and handball, may also benefit
- In essence, carbohydrate loading may be effective for athletes engaged in events that use muscle glycogen as the major energy source and that may lead to a depletion of glycogen in the muscle fibers

Carbohydrate Loading

- Glycogen content in the muscle has been reported to increase about two to three times beyond normal and liver glycogen content nearly doubled following a carbohydrate loading regimen, and this increase may last at least three days in a rested athlete (however, it may be important to taper and rest about two days prior to the event)

Carbohydrate Loading

- Carbohydrate loading may benefit athletes involved in prolonged, intermittent, high-intensity exercise tasks
- Although carbohydrate loading may be an effective technique to enhance performance in prolonged aerobic endurance events, research suggests the most effective protocol is to carbohydrate load and use carbohydrate supplements during the event

Carbohydrates During Training and Competition

DURATION	CHO (g/hour)	TYPE
<30 min	None	–
45-75 min	Very small amounts	Most carb forms or mouth rinse
1-2 hours	Up to 30 g/hour	Most carb forms
2-3 hours	Up to 60 g/hour	Rapidly oxidized sugars (sucrose, glucose, maltodextrin)
>2.5-3 hours	Up to 90 g/hour	Blend glucose + fructose

Carbohydrate Mouth Rinse

- Carbohydrate feeding during endurance exercise is well known to delay fatigue and improve performance
- A growing number of studies have now shown that routinely rinsing the mouth with a carbohydrate-containing solution for 5-10 seconds is associated with improved high intensity endurance exercise performance

Carbohydrate Mouth Rinse

- The consistent performance benefits of 2-3% occur without any ingestion of carbohydrate but are similar in magnitude to those reported when carbohydrate is ingested
- Brain imaging studies have identified areas of the brain activated when carbohydrate is in the mouth

CHO During Training & Competition Example

- Steve is training for a triathlon and is going on a 90-minute bike ride
- Based on the recommendations, Steve should start with 30 g of CHO/hour, for a total of ~45 g on his ride

CHO During Training & Competition Example

- He should pay attention to how he feels
  - Does he have any gastrointestinal (GI) upset?
  - How are his energy levels?
- The recommendations are a starting point, and he can adjust from there based on how he is feeling

Carbohydrates *after* training or event

CHO After Training & Competition

- **Short recovery time**
  - **an athlete should consume 1-1.2 g of CHO/kg/hour (0.45-0.55 g/lb/hour) every hour for the first 4-6 hours post-exercise**
  - **then resume regular dietary habits in order to quickly replenish glycogen stores**

CHO After Training & Competition

- Greater amount of recovery time
  - consuming CHO post-exercise is a good habit for athletes who have a greater amount of recovery time
  - meeting daily CHO needs should be adequate to restore muscle glycogen
  - muscle glycogen stores can generally be normalized within 24 hours (more time may be needed if an athlete follows a low-carbohydrate diet)

Carbohydrates
putting it all together

Recommendations to Support Athlete Performance

1-4 hour pre-exercise	1-4 g/kg body weight
<1 hour pre-exercise	If desired, a small amount of easily digested CHO in an amount and form the athlete prefers
During exercise	Endurance: depends on duration, up to 90 g/h
<8 hours to recover	1-1.2 g/kg/h for four hours
>8 hours to recover	Daily fueling plan adequate to restore muscle glycogen

GI Issues with Carb Intake

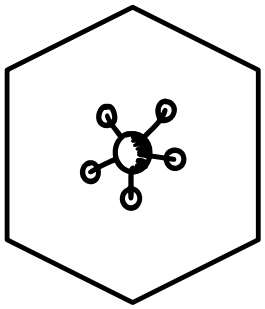
- The stomach is an organ that can be trained
- It is important that an athlete gradually increases the amount of fluid and fuel intake during exercise to meet recommendations
- Consuming more fluid or carbohydrates than an athlete is used to can result in a “sloshy” stomach and other more intense GI discomfort

Fat

- Fat needs for endurance athletes is the same recommended to all by the Food and Nutrition Board of the Institute of Medicine: 20-35% total energy intake
- Fat adaptation describes the process of our bodies becoming better trained to use our fat stores even when we are working at a higher intensity

Fat

- Fat adaptation theory suggests that by becoming fat-adapted, you can spare these glycogen stores by using a higher percentage of fat as fuel, alongside carbohydrate, and prolong the decline in glycogen stores significantly
- While some studies suggest that fat adaptation is possible and for endurance athletes, most fail to find performance advantages or disadvantages and more research needs to be done in this area



ENERGY

HYDRATION, VITAMINS & MINERALS

STRUCTURE

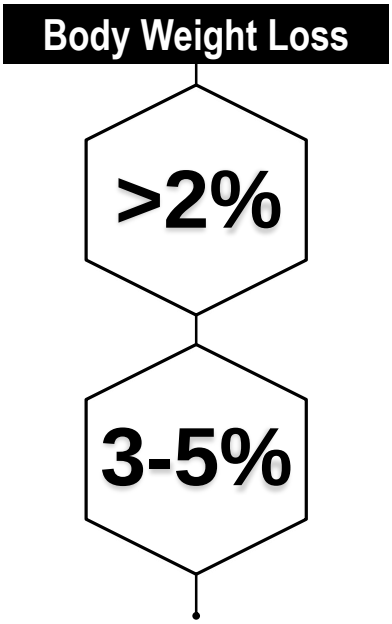
Water

- **Water is essential for every function in the body, and everyone's fluids needs differ depending on their body size, composition, physical activity, and environmental conditions**
- **For sedentary individuals, the dietary reference intake (DRI) for fluid is 16 cups/day for men and 16 cups/day for women; however, athletes have much higher fluid requirements**

Factors Influencing Hydration Status

Dehydration impairs the ability to remove heat

- Cardiovascular strain
- Increased glycogen use
- Altered metabolic & central nervous system function
- Decreased fluid absorption
- Risk of heat illness



impaired cognitive function and aerobic performance

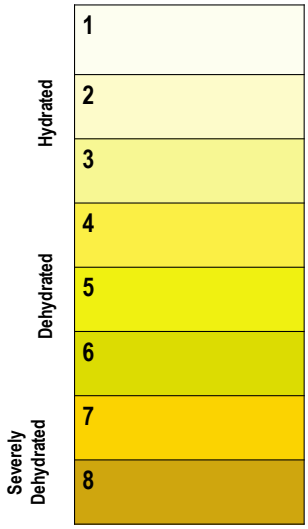
decreased anaerobic/high intensity performance, sport-specific skills, cool-weather aerobic performance

Thomas DT, Erdman KA, Burke LM. *Med Sci Sports Exerc.* 2016;48:543-68

Hydration-monitoring status

Monitoring Hydration Status: Urine Color

- Urine color can be used as a reliable marker of hydration status
- Athletes with a dark urine color of five on a urine color chart are six times more likely to be dehydrated
- A light urine color provides a reasonable assurance the athlete is hydrated



Thomas DT, Erdman KA, Burke LM. *Med Sci Sports Exerc.* 2016;48:543-68

Sweat Rate Calculation

- To measure how much fluid an athlete loses sweating rate will need to be measured. Here are the steps:
  - obtain body mass before practice
  - know the mass of the food and fluids that you consume during this session

$$\frac{\text{Body Mass}_{\text{PRE-EX}} - \text{Body Mass}_{\text{POST-EX}} - \text{Fluid Intake}_{\text{EX}} + \text{Urine Loss}_{\text{EX}}}{\text{Exercise Duration}}$$

Sweat Rate Calculation

- To measure how much fluid an athlete loses sweating rate will need to be measured. Here are the steps:
  - know the mass of any urine or stool lost during this training
  - obtain post-exercise body weight after toweling dry

$$\frac{\text{Body Mass}_{\text{PRE-EX}} - \text{Body Mass}_{\text{POST-EX}} - \text{Fluid Intake}_{\text{EX}} + \text{Urine Loss}_{\text{EX}}}{\text{Exercise Duration}}$$

Sweat Rate Calculation

- To measure how much fluid an athlete loses sweating rate will need to be measured. Here are the steps:
  - know how long your training session lasted – meaning how long from the pre-exercise to post-exercise body mass

$$\frac{\text{Body Mass}_{\text{PRE-EX}} - \text{Body Mass}_{\text{POST-EX}} - \text{Fluid Intake}_{\text{EX}} + \text{Urine Loss}_{\text{EX}}}{\text{Exercise Duration}}$$

Example Hydration Strategy

- Example of an athlete that conducted a sweat test during training and how to use that information to build a hydration plan for a marathon
  - sweat test exercise duration: 90 minutes
  - sweating rate: 1.5 L / 1.5 hours = 1 L per hour
  - four-hour marathon = 4 L or 4 kg body mass loss
  - drinking volume (sweat loss – 2% window): 4-1.4 = 2.6L
  - hydration strategy: 2.6 L/4 h = 650 ml/h OR 220 ml/20 min

Factors Impacting the Variability in Sweating rate

- Exercise intensity
- Body size
- Environmental conditions (temperature, humidity, solar load, wind)
- Heat acclimatization
- Fitness
- Clothing/equipment worn
- Body composition
- Hydration status
- Age (maturation)
- Genetics
- Methodology

- Sodium losses are highly variable, average is usually ~1 g/L
- Sodium before and after training/competition will help athletes retain fluids
- Replacing sodium lost during exercise becomes especially important when the athletes have high sweat rates, are salty sweaters, or duration is greater than two hours

- Although skeletal muscle cramps are typically caused by muscle fatigue, they can occur with athletes from all types of sports in a range of environmental conditions and may be associated with hypohydration and electrolyte imbalances
- Athletes who sweat profusely, especially when overlaid with a high sweat sodium concentration, may be at greater risk for cramping, particularly when not acclimatized to the heat and environment

Hyponatremia

- Hyponatremia results from decreased sodium concentration below 135 mmol/L
- The longer it remains low, the greater the risk of severe symptoms, even death
- Factors associated with hyponatremia:
  - overdrinking water
  - longer duration events
  - large sweat sodium losses

Stachenfeld NS. *Sports Science Exchange.* 2014;27(122):1-5
Murray B, Stofan J, Eichner RE. *Sports Science Exchange.* 2003;16(1):1-6

Hyponatremia

- Hyponatremia can also occur following prolonged exercise, in which case it may be known as exercise-associated hyponatremia (EAH)
  - EAH as a serum sodium concentration below the normal reference range, or less than 135 mmol/liter (135 mEq/liter)
  - milder forms are 130-134 mmol/liter and may be asymptomatic, but not always

Hyponatremia

- Signs and symptoms of mild hyponatremia usually occur when serum sodium goes below 130 mmol/liter and may include the following:
  - bloating
  - puffiness of hands and feet
  - nausea
  - vomiting
  - headache

Hyponatremia

- Severe cases, below 120 mmol/liter, may cause massive brain swelling, which may be associated with the following:
  - seizures
  - coma
  - respiratory arrest
  - permanent brain damage
  - death

Hyponatremia

- 2002 Boston marathon study
  - researchers tested 488 runners following the race
  - 13% had a serious fluid and salt imbalance from drinking too much water or sports drinks
  - one 28-year-old woman died from hyponatremia

Hyponatremia

- In addition to affecting endurance athletes exercising in the heat, EAH has been documented in hikers, climbers, trekkers, and cold-climate endurance athletes
- Treatment of individuals with symptomatic hyponatremia is a medical emergency, and transportation to a hospital is essential – infusion of hypertonic solutions may be necessary

Hyponatremia

- Various risk factors have been identified that predispose individuals to development of EAH in marathons and other endurance events, including the following:
  - excessive drinking of fluids before, during, and after the event
  - considerable weight gain over the course of the event
  - slower finishers
  - females
  - low body weight

Hyponatremia

- Various risk factors have been identified that predispose individuals to development of EAH in marathons and other endurance events, including the following:
  - heat (unacclimatized, poorly trained competitors)
  - high sweat sodium losses
  - race inexperience
  - nonsteroidal anti-inflammatory drug (NSAID) use, altered kidney functions to excrete fluids

Hyponatremia

- The American College of Sports Medicine (ACSM), in its position stand on fluid replacement, indicates that fluid consumption that exceeds sweating rate is the primary factor leading to exercise-associated hyponatremia

Dehydration

- Dehydration impairs proper carbohydrate utilization, heart rate, core temperature, perceived exertion, and muscle glycogen use
- Mild dehydration can impair mood, reduce alertness, concentration, and short-term memory, as well as decrease fine motor skills

Start Exercise Well-Hydrated

- When heavy sweating is expected, drink 2-3 cups of fluid four hours before exercise – this allows excess fluid to be excreted in urine, if urine output is low drink 5-12 oz more
- These fluids should allow both water and sports drinks in order to help replace the electrolytes lost in sweat

Drink Fluids and Ingest Sodium During Exercise

- Athletes should drink every 10-20 minutes depending on their sweat level (no need to drink excessively, athletes should not gain weight from fluid during exercise)
- Sodium intake of 1 g/hour is recommended during prolonged exercise with heavy sweat-loss (salt requirements in athlete's diet is much higher due to the amount they lose in sweat)

Hydration Timing and Amounts

~4 hours before exercise	~2 hours before exercise	During exercise	After exercise
5-7 mL/kg fluid	3-5 mL/kg fluid *IF urine is dark or not produced	Fluid with sodium, amount based on body weight changes	20-24 oz of fluid with sodium for every pound body weight lost during exercise

Shirreffs S & Sawka M. *Journal of Sports Sciences*. 2011;29:S39-S46

Vitamins and Minerals

- Endurance and ultra-endurance athletes have higher requirements for some vitamins and minerals, including:
  - B vitamins
  - iron
  - calcium
  - vitamin C
  - vitamin E
  - sodium
  - potassium

B Vitamins

- B vitamins like thiamin, riboflavin, and niacin are required for energy production pathways
- Thiamin
  - has a central role in the metabolism of glucose and is essential for the normal functioning of the nervous system and energy derivation from glycogen in the muscles
  - deficiency symptoms may occur in several weeks and include loss of appetite, mental confusion, muscular weakness, and pain in the calf muscles

B Vitamins

- B vitamins like thiamin, riboflavin, and niacin are required for energy production pathways
- Thiamin
  - two factors that increase the need for thiamin are exercise and high carbohydrate intake – a deficiency of thiamin could prove to be detrimental to the active individual who might rely on high levels of carbohydrate metabolism for aerobic energy production during exercise, such as endurance athletes

B Vitamins

- Niacin
  - also known as nicotinic acid, nicotinamide, or the antipellagra vitamin
  - a water-soluble vitamin in the B complex and is sometimes erroneously referred to as vitamin B3
  - although niacin deficiency was prevalent in the past, the enrichment of foods with niacin has nearly eliminated this problem

B Vitamins

- Niacin
  - in theory, physical performance would be impaired by a niacin deficiency because the production of energy from carbohydrate could be impaired – both aerobic- and anaerobic-type performances could be affected

B Vitamins

- Riboflavin
  - important for the formation of several oxidative enzymes known as flavoproteins, which are involved in energy production from carbohydrate and fats in the body cells
  - deficiencies are very rare

B Vitamins

- Sources
  - thiamin – fortified and whole grains, legumes, wheat germ, nuts, pork
  - riboflavin – milk, yogurt, bread and cereal products, mushrooms, cottage cheese, eggs
  - niacin – beef, poultry, legumes, liver, seafood, fortified and whole grains, mushrooms

Iron

- Iron aids in the formation of compounds that are essential for transporting and utilizing oxygen, making it essential for aerobic activities and endurance training
- Iron can be lost through hemolysis (the breakdown of red blood cells) from repeated impact, irritation from equipment and body friction, oxidative stress, the consumption of non-steroidal anti-inflammatory drugs, and sweating

Iron

- Exercise-induced iron-deficiency anemia is notably high in athletic populations, particularly those with heavy training loads – this could include some male athletes, such as gymnasts, wrestlers, and distance runners

Iron

- Relative to distance runners, researchers have noted that among competitive athletes, marathoners are at greater risk to develop anemia and other clinical syndromes that may be associated with inadequate dietary intake of iron
- In particular, female athletes are at risk, and recent studies have documented poor iron status and associated declines in both cognitive and physical performance

Iron

- Sources
  - beef
  - poultry and fish
  - soy products
  - dried fruits
  - legumes
  - whole grains
  - fortified cereals
  - green leafy vegetables

Calcium

- Calcium is a bone strengthening mineral, is required for proper nerve function, it helps to produce fibrin which is the protein responsible for the structure of blood clots, and it initiates muscle contraction and relaxation of smooth muscle, skeletal muscle, and the heart
- All of the functions that calcium aids in are essential for endurance athletes to maintain intensity and duration of their training

Calcium

- Sources
  - milk
  - yogurt
  - cottage cheese
  - hard cheese
  - fortified foods
  - juices

Vitamins C and E

- Vitamins C
  - water-soluble vitamin
  - has a number of different functions in the body, some of which have important implications for the physically active individual
  - principal role is in the synthesis of collagen, which is necessary for the formation and maintenance of the connective tissues of the body, such as cartilage, tendon, and bone

Vitamins C and E

- Vitamins C
  - involved in the formation of certain hormones and neurotransmitters, such as epinephrine (adrenaline), which are secreted during stressful situations such as exercise
  - a powerful antioxidant, which helps it contribute to normal function of the immune system

Vitamins C and E

- Vitamins E
  - fat-soluble vitamin
  - works in concert with other antioxidants, such as vitamin C, to maintain its ability to help prevent the oxidation of unsaturated fatty acids, thereby protecting the cell from damage

Vitamins C and E

- Vitamin C sources
  - citrus fruits
  - berries
  - melon
  - tomatoes
  - bananas
  - green leafy vegetables
  - sweet potatoes
- Vitamin E sources
  - nuts
  - seeds
  - wheat germ
  - fortified cereals
  - strawberries

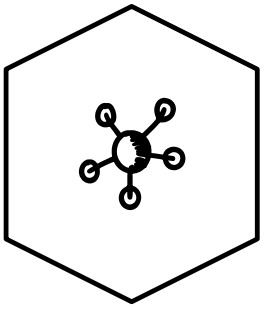
Sodium and Potassium

- Sodium is an important element in a number of body functions – as the principal electrolyte in the extracellular fluids, it primarily helps maintain normal body fluid balance and osmotic pressure
- In conjunction with several other electrolytes, sodium is critical for nerve impulse transmission and muscle contraction

Sodium and Potassium

- Potassium also plays an important role in the energy processes in the muscle; it helps in the transport of glucose into the muscle cells, the storage of glycogen, and the production of high-energy compounds

While most athletes can meet vitamin and mineral needs with food intake, some may need supplements



ENERGY

HYDRATION, VITAMINS & MINERALS

STRUCTURE

Protein

- Human body is about 45% protein
- All athletes need protein for success
- The primary functions of proteins in the human body are:
  - structure – collagen
  - movement – contractile proteins
  - immune function – antibodies
  - transport – hemoglobin
  - hormones
  - enzymes – facilitate biochemical reactions
  - cell signaling, or communication pathways in cells

Protein

Animal Proteins

Meat
- Beef
- Poultry
- Seafood

Dairy
- Milk
- Cheese
- Yogurt

Eggs – highest quality protein

Animal proteins have about seven grams of protein per ounce

Alternative Proteins

- Quinoa
- Soy
- Tofu
- Pea protein
- Legumes, nuts, seeds
- Bone broth
- Collagen
- Non-dairy milk
- Sprouted grain bread
- Meat alternatives
- Cricket flour

Alternative proteins may have less protein per ounce compared to animal proteins

Protein

- Protein intake of 1.2-2.1 g/kg/day is sufficient for endurance activity as long as the athlete is consuming adequate carbohydrates and calories

Leucine

- Leucine, along with isoleucine and valine, are branched-chain amino acids (BCAAs) that make up nearly 1/3 of muscle protein
- Leucine stimulates protein synthesis in muscle
- High intake of BCAAs may decrease the rate of protein breakdown, improve performance, and have a sparing effect on muscle glycogen

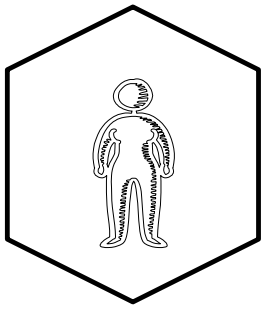
Leucine-Containing Foods

- Milk
- Eggs
- Soy
- Fish
- Poultry
- Beef
- Pork

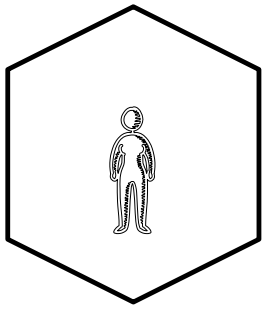
Calculating Protein Needs

- Elite male endurance athlete, training for an Ironman; weighs 158 lb
- Requires 1.5-1.8 g/kg/day
  - 158 lb / 2.2 = 71.8 kg
  - 71.8 x 1.5 = 107.7
  - 71.8 x 1.8 = 129
  - protein needs ~108-129 g/day

Protein for Recovery



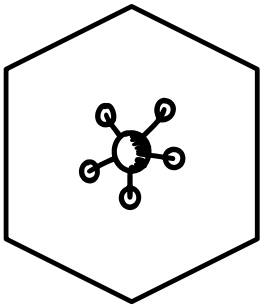
0.25-0.30
g/kg



288 lb
X 0.30 (g/kg)
39 g PROTEIN

135 lb
X 0.30 (g/kg)
18 g PROTEIN

Moore DR. *Front. Nutr.* 2019;6:147



ENERGY

HYDRATION, VITAMINS & MINERALS

STRUCTURE

Summary

- Endurance athletes' fueling and hydration needs are unique and require specific replacement during and after exercise to perform optimally
- Therefore, endurance athletes need to experiment and adapt
- Consume enough calories per day
- Consume carbohydrates at 6-10 g/kg/day for moderate training or 8-12 g/g/day for heavy training

Summary

- Hydration before, during and after events is key
- Protein intake of 1.2-2.1g/kg/day it sufficient for endurance athletes
- Consume a variety of foods to meet vitamin and mineral needs

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Nutrition for Endurance Athletes

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