Energy Balance

The Relationship Between Calories in and Calories Out

Despite potential underlying genetic and environment contributions, the fundamental components of energy balance are well preserved across species suggesting that being overweight/obese is not a uniquely human problem. If your pet becomes obese, your vet is not going to suggest having them drink more water, feed them apple cider vinegar, apply muscle stimulation devices, or wrap their abdomens in plastic to make them sweat more. They will simply tell you to feed your pet less and have them be more physically active. If the fundamental components of energy balance are the same, how do we rectify such recommendations against popular assertions that 'counting calories' does not work?

Topics: Direct Calorimetry — Atwater Indirect System — Metabolic Rate — Thermic Effect of Food — Activity Expenditure — Habitual Energy Balance — Starvation Response — Relative Energy Deficiency Syndrome

Energy Balance — The point of energy homeostasis between energy consumed and energy expended

The basic framework of energy balance suggests that changes in body composition can be predicted based on the energetic balance between sources of energy intake and sources of energy expenditure. If more energy is taken in than expended, adipocytes should attempt to store the excess energy resulting in accumulation of fat stores. If more energy is expended than taken in, metabolic processes will need to use the excess energy stored within white adipocytes to compensate — resulting in reduction of fat stores.

In terms of sources of energy taken in, human physiology essentially restricts this such that we only need to focus on the food consumed. The energy taken in is reflected by the caloric content of the food. From a scientific perspective, a food calorie is actually a kilocalorie (kcal) and is roughly equivalent to 4,184 joules. Within the U.S., this is typically just referred to as a 'calorie'. Outside of the U.S., the use of kilocalorie has been standard, but the U.S. nomenclature has caused confusion resulting in the field gradually shifting to begin using joules. As a unit of measure, a kilocalorie reflects the amount of energy needed to raise the temperature of one kilogram of water by one degree Celsius.

Using a **calorimeter**, a known quantity of food would be dehydrated, sealed in an oxygen rich container, and then ignited. By measuring the change in the temperature in the water surrounding the food container, the caloric content per gram of food could be obtained. So food substances that burn without creating much heat are considered as lower calorie than food substances that create substantial heat when burned.

Modern caloric assessments now use variants of the **Atwater indirect system** which use established energetic values for energy–containing nutrients rather than calorimetric measurements directly. The general factor system allocates energy values of 4 kcal per gram for carbohydrates, 9 kcal per gram for fat, and 4 kcal per gram for protein. Once the macronutrient profile of the food is known, the energetic values can be added up.

> So for example, a typical donut is made of around 33 grams of carbohydrates ($33 \times 4 = 132$ kilocalories), 16 grams of fat ($16 \times 9 = 144$ kilocalories), and 5 grams of protein ($5 \times 4 = 20$ kilocalories) and is therefore estimated to be around 296 kilocalories (1.2 megajoules) which is energetically equivalent to a little more than a stick of dynamite.

Sources of energy expenditure reflect all the ways in which the body uses the energy. So this includes the energy expended by physiological processes just to keep the body alive, the energy expended in the digestion and storage of food, and energy expended through physical activities. Although unprocessed energy (e.g., energy consumed but then excreted in waste) should technically be considered, it represents such a small amount that it is considered insignificant and is rarely measured. The exception to this being when pharmaceutical agents are used to specifically block the absorption of specific components of food, rendering it necessary to account for this unprocessed energy.

Metabolic Rate — The amount of energy required to sustain the body's vital functions in the waking state.

The largest component of energy expenditure is metabolic rate, which reflects the energetic cost of running your heart (440 kcal per kg per day), kidneys (440 kcal per kg per day), brain (240 kcal per kg per day), liver (200 kcal per kg per day), and skeletal muscle (13 kcal per kg per day) just to keep all the systems going. Ideally, we are interested in the basal rate which reflects the lowest energy expenditure necessary, when all of our systems are essentially on idle. Although the heart and kidneys have the highest energy expenditure per kilogram of mass, their small mass results in only accounting for around 10% of overall metabolic rate each. On an overall basis, the two largest contributors to metabolic rate are skeletal muscle — accounting for approximately 25% of metabolic rate, and the brain — accounting for approximately 24% of metabolic rate.

The highly variable nature of metabolic rate is thought to primarily be the result of individual differences in the metabolism of the skeletal muscle and brain, both in terms of overall mass and the energetic cost per kg of mass. Genetics are believed to be particularly important to the energetic activity of these tissues. On a population level, individuals with more masculine body types exhibit higher metabolic rates than individuals with more feminine body types; but such differences go away once differences in fat-free mass are taken into account. Similarly, if an individual is able to sustain muscle mass and brain mass/activity as they age then metabolism does not appear to slow with aging. However, if they are unable to oppose age-, or disease-related reductions in muscle mass and declines in brain mass/cognitive engagement, metabolic rate also appears to slow at a rate of approximately 3 to 5% per decade after 30 years of age, and 7 to 10% per decade after age 60. So if muscle mass or brain mass/activity declines, so too will metabolic rate. Some perspectives on energy balance refer to changes in metabolic rate associated with gains/losses of muscle mass as adaptive thermogenesis, but this is largely a conceptual differentiation rather than practical one as any changes in muscle mass would be reflected in the measurement of metabolic rate.

Thermic Effect of Food — The amount of energy required for digestion, absorption, processing, and storage of food taken in.

In order for the body to obtain usable energy from the food consumed, it is necessary to expend energy to digest, absorb, process, and potentially store such energy. This energy expenditure is characterized by the thermic effect of food. This process usually peaks around 30 to 90 minutes after eating and lasts for 3 to 6 hours. The larger the meal size, the more energy expenditure is required and the longer the thermic effect of food persists. Part of the justification for weight loss strategies that encourage the consumption of more frequent but smaller meals is based on this concept. By eating more frequently, the thermic effects of food consumption would overlap potentially increasing the calories expended in this process. Unfortunately, the thermic effect of food is most strongly tied to the caloric content of the food. So eating smaller but more frequent meals does not alter the energy necessary to digest, absorb, process, and store the food.

The magnitude of the thermic effect of food is **approximately 10% of the kilocalories consumed**. So an individual who consumes 2000 kilocalories will need to expend 200 kilocalories to digest, absorb, process, and store the food. However, while the 10% rule has the benefit of being easy to remember and implement, the energetic cost has been observed to vary by macronutrient profile. The thermic effect of food is approximately 7.5% of the kilocalories consumed as carbohydrates, 1.5% of the kilocalories consumed as fat, and 25% of the kilocalories consumed as protein. To further add complexity, the energy required for processing the calories also appears to relate to a number of factors specific to the food (e.g., fiber content, level of processing) and the individual, with obese individuals exhibiting reductions in the thermic effect of food.

The final aspect of energy expenditure reflects the energy expended through physical activity. While some frameworks of energy balance further subdivide this into exercise (EAT; exercise activity thermogenesis) and non–exercise related energy expenditure (NEAT; non-exercise activity thermogenesis), physical activity ultimately includes all those activities that occur throughout the day over and above basal levels (laying on your back doing nothing). The larger the muscle groups involved in the activity, the more energy that is required for that movement.

Energy expenditure related to physical activity is typically characterized in terms of its energetic cost (kcal/kg/min $\times$ body weight (kg) $\times$ time (min)). Using established energetic cost values, it is possible to estimate how many calories of energy are consumed as a function of body weight and the time the activity is engaged in. When you use a piece of exercise equipment and it wants to know how much you weigh, it uses that information — along with its own internal information about the duration of the activity and the energetic cost of the activity — to determine how many calories you are expending.

> What would the energetic cost of a 60 kg (132 lb) individual engaging in:
>
> **10 min of Cooking (0.035 kcal/kg/min)**
>
> $$Energy\ cost\ =\ 0.035\ \times\ 60kg\ \times\ 10min\ =\ 21\ kilocalories$$
>
> **10 min of Walking (3mph, 0.066 kcal/kg/min)**
>
> $$Energy\ cost\ =\ 0.066\ \times\ 60kg\ \times\ 10min\ =\ 39.6\ kilocalories$$
>
> **10 min of Running (6mph, 10 min mile, 0.175 kcal/kg/min)**
>
> $$Energy\ cost\ =\ 0.175\ \times\ 60kg\ \times\ 10min\ =\ 105\ kilocalories$$

The relative percentage of overall energy expenditure that metabolic rate, thermic effect of food, and physical activity will each account for will vary. If you do relatively little physical activity, metabolic rate and thermic effect of food will necessarily account for a greater overall percentage of energy expenditure. However, in general, metabolic rate accounts for 60 to 75% of overall energy expenditure for most individuals, while physical activity accounts for between 15 and 30%, and thermic effect of food accounts for between 10 to 15%.

The Utility of Energy Balance

The basic framework of energy balance is that by tracking the calories consumed, the calories expended through the thermic effect of food, the calories expended through metabolic rate, and the calories expended through physical activity, it becomes possible to predict changes in body composition (typically focused more on adiposity stores). Therefore, changes in body composition can be incurred in an intentional way by altering the caloric balance. If the framework of energy balance is scientifically valid, why then is this 'calorie counting' approach not typically effective at obtaining the intended changes in body composition? At the same time, if it is not typically effective, how then do medical clinics and specialty practices use this approach effectively?

When we look at the actual implementation of calorie counting practices, it becomes readily apparent that societal tendencies in how this approach is implemented are in large part to blame for failure or success in obtaining intended results. Beyond the simple misuse of body mass instead of body composition; this is commonly attributed to three dominant factors: (1) the extent to which the calories that are counted reflect the true caloric values, (2) the temporal nature of energy balance, and (3) the magnitude of energy imbalance.

Habitual Energy Balance — The concept of energy balance applied to persistent chronic lifestyle behaviors.

The nature of the energy balance equation lends itself to focusing only on daily balance. An individual tracks what they eat, what they do, and obtains their balance for the day. So if they consume 2,000 kilocalories but expend 2,100 kilocalories, they should see a reduction of 100 kilocalories. A kilogram of fat is approximately 7,700 kilocalories (1 pound of fat is 3,500 kilocalories). So that reduction should be about 1.3% of a kilogram of fat (2.9% of a lb of fat). Using this process we can determine how many miles it would take to burn off a pound of fat (3,500 kilocalories). At 105 kilocalories per mile (from the example above), it would take more than 33 miles to burn off that one pound and that is assuming that no additional foods or calories were consumed in the process or following.

When people apply such a daily energy balance perspective, they tend to think in terms of trade offs. If they want to eat a particular food, they only need to increase their activity to burn off those calories. Or if they don't eat a particular food, then they don't have to spend the extra few minutes on the treadmill. From a mathematical perspective, this makes sense as while caloric consumption might change, so long as physical activity also changes then the net result will be the same. The depressing reality is that while the math works out for daily energy balance, it completely ignores the various psychological and sociological factors that can also come into play when energy consumption falls too low or physical activity expenditure raises too high. Specifically, if there is insufficient energy intake, we tend to reduce our physical activity expenditures and increase psychological pressures to consume food. Conversely, exceptionally high levels of physical activity expenditure has been found to result in physiological alterations that reduce energetic expenditures by either becoming more efficient or diminishing the function of unnecessary systems. Physiologically our systems do not comply with such a simple daily energy balance perspective as the focus needs to be on habitual energy balance.

Focusing energy balance on persistent chronic lifestyle behaviors means that instead of tracking one day at a time, the balance is based upon the typical behavioral tendencies. So the calories consumed would not be reflective of a single day, where you might starve yourself one day and binge the next (e.g., cheat day) but rather reflect the average pattern of caloric consumption over a longer period of time. This is where some of the most interesting nuances of energy balance become apparent. Both caloric consumption and physical activity appear to be **time-lagged** such that changes in body composition are not occurring in real time but are reflective of previous behaviors. When dietary practices are stable and consistent, evidence suggests that energy balance related to caloric consumption appears based upon habitual caloric intake over a period of the last 3 weeks. Energy balance related to physical activity also appears to exhibit a time-lagged effect based upon habitual physical activity behaviors over a period of the last 8 weeks. So sudden dietary and activity changes will not immediately have an effect on adiposity stores.

Starvation Response — When exposed to dramatically reduced caloric consumption, physiological systems will aggressively break down muscle tissue to reduce energy expenditure and will prioritize the storage and preservation of fat.

The final aspect important for understanding the success and failures in application of the energy balance framework relate to the **magnitude of energy imbalance imposed**. The evidence surrounding failures in implementation point to a relatively simple and consistent observation that too large of an energy imbalance was created, which brought online other processes that actively worked against the intended goals. Conceptually, consider the situation in which an individual becomes trapped and is unable to secure a source of food. So calories consumed would go to zero, as would the thermic effect of food.

In this example, we might assume that the individual would exert some physical activity associated with attempting to free themselves, but unless they do so their metabolic rate will continue churning through stored energy sources until they die. It is biologically advantageous then that in times of starvation that the body can bring online strategies to change primary energy sources and begin breaking down muscle. Since muscle is the dominant contributor to metabolic rate, this results in metabolic slowing which preserves fat stores. Additionally, the system becomes biased so that energy that is taken in is preferentially allocated towards fat storage. This likely serves as a further protective mechanism as the additional fat stores provide an energetic buffer.

The difficulty with energy balance results from our physiological systems being hard-wired for survival. Evidence indicates that survival mechanisms such as metabolic slowing and preferential fat storage are brought online quite rapidly and in response to relatively minimal deficits in energy availability. Early research in this area suggested that these survival mechanisms were only brought online when calories consumed fell below 1.2× basal metabolic rate. However, military research and evidence from famine/disaster conditions indicates that these survival mechanisms begin to be initiated when **energy deficiency reaches around 10 to 15% of habitual calories consumed** with more dramatic effects the larger the deficit.

So a persistent energy deficiency of 100 kilocalories in an individual who regularly consumes around 2,000 kilocalories per day would likely result in gradual reductions in adipose tissue without triggering starvation responses as the deficit is only 5% of their calories consumed. Whereas an individual with a persistent energy deficiency of 500 kilocalories, regularly consuming around 2,000 kilocalories per day would likely experience metabolic slowing and preferential fat storage as the deficit is 25% of the calories consumed. Even when energy deficiency is not persistent, when dietary practices are highly inconsistent, metabolic slowing also begins to occur to bias the system to accumulate fat. Using this approach, the World Health Organization requires food rations to provide at least 1,700 kilocalories per person per day, with the recommendation that it provide 2,100 kilocalories per person per day.

Relative Energy Deficiency Syndrome — An inadequacy of energy to support the range of body functions involved in optimal health and performance.

Although more popularly applied for the purposes of 'weight' loss and adipose reduction; the nature of the energy balance framework also means that it provides a way of understanding the energetic needs of athletes and military personnel. NATO (North Atlantic Treaty Organization) allied militaries require field rations to provide a minimum of 3,600 kilocalories per day and recommends active combatants receive 4,200 to 4,800 kilocalories per day to compensate for the increased energetic expenditures. When persistent energy deficits between dietary energy intake and energy expenditure occur, performance begins to degrade.

This issue rose in popularity in the 1990's in regards to research identifying the link between persistent energy deficiency, reductions in bone mineral density, and menstrual dysfunction within female athletes/military personnel; a condition referred to as the **Female Athlete Triad**. However, modern perspectives highlight that it is not just females that experience health related consequences of persistent energy deficiency, nor are the consequences of energy deficiency restricted to just menstrual function and bone health. Thus the new terminology of **Relative Energy Deficiency Syndrome** (REDs) has been adopted, although some frameworks refer to it as Relative Energy Deficiency in Sport (RED-S) to highlight the negative influences on performance as well as health.

Energy Availability —

$$\frac{Calories\ Consumed\ (kcal) - Exercise\ Expenditure\ (kcal)}{Fat\ Free\ Mass\ (kg)}$$

The core concept of Relative Energy Deficiency Syndrome is a mismatch between energy intake and the energy expended in exercise. When an individual has low energy availability, there is insufficient energy to support the physiological functions necessary to maintain optimal health and performance so physiological degradation begins to occur. Although some perspectives suggest there may be different optimal levels for energy availability between males and females; evidence appears to suggest that energy availability below clinical levels introduces physiological issues across a wide range of systems including immunological, gastrointestinal, cardiovascular, psychological, metabolic, hormonal, and osteological. This can manifest as chronic fatigue, difficulty with concentration/coordination, irritability, depression/anxiety, difficulty adding muscle mass/size, decreased training response, reductions in endurance, impaired judgement, and increased risk of injury.

> **Optimal Energy Availability** — ≥ 45 kcal/kg FFM. Provides adequate energy for all physiologic functions and maintenance of body mass.
>
> **Subclinical Low Energy Availability** — 30 to 45 kcal/kg FFM. May be tolerated for short periods in well constructed body composition programs.
>
> **Clinical Low Energy Availability** — < 30 kcal/kg FFM. High risk of health implications with impairment of bodily systems, detraining effects, and performance decrements.

Part of the emphasis of Relative Energy Deficiency in Sport (rather than as a syndrome) is that for athletes and military personnel engaged in excessive levels of physical activity at higher intensities, there is often not a strong biological imperative to match energy intake to activity-induced energy expenditure such that appetite is not a reliable indicator of energy balance. So it can be easy for such individuals to unintentionally place themselves in a situation where their energy availability begins to compromise health and performance.

Further, training contexts that have historically used higher intensity, long duration activity with minimal food consumption may compromise the potential benefits of the training. For instance, highly-rigorous military training courses such as 'Ranger School' and special operations selection programs place candidates in situations of nearly continual physical exertion with minimal food intake such that energy availability estimates place these individuals at less than 12 kcal/kg FFM.

Although the conditions are meant to place candidates under extreme stress situations, it also compromises their operational readiness with assessments indicating 15 to 30 lb reductions in fat-free mass, alongside declines of almost 20% in strength and power. Consistent with findings from the Minnesota starvation study in 1950, candidates also exhibit insatiable hunger and rapid accumulation of adipose tissue following the training/selection course that persists for a prolonged period. Despite this, high school and collegiate athletics programs often idealize such training as optimal ways to enhance performance and implement aspects of these training/selection programs in inappropriate contexts.

Additional Resources:

Mountjoy, M., Sundgot-Borgen, J., Burke, L., Ackerman, K. E., Blauwet, C., Constantini, N., ... & Budgett, R. (2018). International Olympic Committee (IOC) consensus statement on relative energy deficiency in sport (RED-S): 2018 update. International Journal of Sport Nutrition and Exercise Metabolism, 28(4), 316-331. http://dx.doi.org/10.1123/ijsnem.2018-0136

Energy Balance

The point of energy homeostasis between energy consumed and energy expended

Positive Balance
Intake exceeds Expenditure

Adipocytes should store excess energy for later use, resulting in accumulation of fat stores.

Negative Balance
Expenditure exceeds Intake

Metabolic processes will need to use the excess energy stored within white adipocytes to compensate — resulting in reduction of fat stores.

Energy
Intake

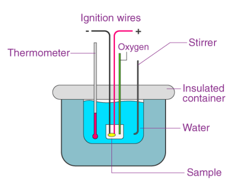
Food Consumption

- From a scientific perspective, a food calorie is actually a kilocalorie (kcal) and is roughly equivalent to 4,184 joules.
  - Within the U.S., this is typically just referred to as a 'calorie'.
  - Outside of the U.S., the use of kilocalorie has been standard.
    - But the U.S. nomenclature has caused confusion resulting in the field gradually shifting to begin using joules.

What is a
Calorie?

A kilocalorie reflects the amount of energy needed to raise the temperature of one kilogram of water by one degree Celsius.

Food substances that burn without creating much heat are considered lower calorie than foods that create substantial heat when burned.



Energy
Intake

Food Consumption

Modern caloric assessments now use variants of the Atwater indirect system which use established energetic values for energy-containing nutrients rather than calorimetric measurements directly.

4 kcal per gram	9 kcal per gram	4 kcal per gram
Carbohydrates	Fat	Protein

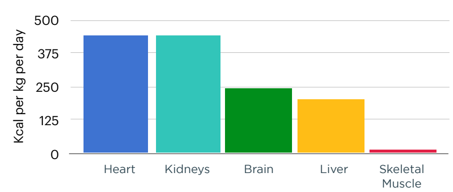
4-9-4 Carb-Fat-Protein

Energy
Balance

				Energy In		**Energy Out**
Caloric Balance	=	Food Ingested	–	Metabolic Rate Thermic Effect of Food Physical Activity ~~Energy Excreted in Waste~~

Metabolic Rate

The amount of energy required to sustain the body's vital functions in the waking state.



Skeletal Muscle
25%
of total metabolic rate

Brain
24%
of total metabolic rate

Energy

Expenditure

Metabolic Rate

- Metabolic rate also appears to slow with aging:
  - ~3 to 5% per decade after 30 years of age
  - ~7 to 10% per decade after age 60
  - If they are unable to oppose age–, or disease–related reductions in muscle mass and declines in brain mass/cognitive engagement.
- Some perspectives on energy balance refer to changes in metabolic rate associated with gains/losses of muscle mass as **adaptive thermogenesis.**

Energy Expenditure

Thermic Effect of Food

Thermic Effect of Food

The amount of energy required for digestion, absorption, processing, and storage of food taken in.

- Energy cost of digestion, nutrient absorption, assimilation, processing, storage, and synthesis of protein, fat, and carbohydrate.
- Usually peaks about 30 to 90 minutes after eating, but depending on the size and content of the meal may last as long as 4 to 6 hours.
  - This is part of the justification behind eating more frequent smaller meals!

Energy Expenditure

Thermic Effect of Food

Thermic Effect of Food

The amount of energy required for digestion, absorption, processing, and storage of food taken in.

- The magnitude of the thermic effect of food is approximately 10% of the kilocalories consumed.
  - An individual who consumes 2000 kilocalories will need to expend 200 kilocalories to digest, absorb, process, and store the food.

Energy Expenditure

Thermic Effect of Food

- However, while the 10% rule has the benefit of being easy to remember and implement, the energetic cost has been observed to vary by macronutrient profile.

7.5% of the kilocalories consumed as carbohydrates

1.5% of the kilocalories consumed as fat

25% of the kilocalories consumed as protein

- To further add complexity the energy required for processing the calories also appears to relate to:
  - A number of factors specific to the food (e.g., fiber content, level of processing) and
  - The individual, with obese individuals exhibiting reductions in the thermic effect of food.

Energy Expenditure

Physical Activity

- Physical activity includes all those activities that occur throughout the day over and above basal levels (laying on your back doing nothing).
- The larger the muscle groups involved in the activity, the more energy that is required for that movement.
- Based on activity and intensity we can estimate energy cost as:

  kcal/kg/min * body weight (kg) * time (min)

The Utility of

Energy Balance

- Societal tendencies in how this approach is implemented are in large part to blame for **failure** or **success** in obtaining intended results.
  - Beyond the simple misuse of body mass instead of body composition.
- This is commonly attributed to three dominant factors:
  - The extent to which the calories that are counted reflect the true caloric values
  - The temporal nature of energy balance
  - The magnitude of energy imbalance

The Nature of

Energy Balance

Daily Balance

On a given day, the individual tracks what they eat, what they do, and obtains the balance.

The vast majority of individuals follow this approach.

Very little evidence that this approach is effective.

Habitual Balance

Energy balance is a function of typical behavioral tendencies. The typical dietary and activity practices that are representative of habitual behaviors.

The approach successfully used by medical weight loss strategies and specialty service clinics.

The Nature of

Energy Balance

Daily Balance

Comprehensively & accurately track every calorie consumed each day.

Comprehensively & accurately track every calorie expended each day.

'Compensate' for any additional calories consumed by adding activity calories.

Calories rest each night.

Habitual Balance

Tracking calories is a tool used to help an individual understand their typical caloric balance & make healthier choices.

Tracking calories might only occur over a period of a few weeks.

Focus is on generally increasing activity calories and reducing excess food consumption on a habitual basis.

The Nature of

Energy Balance

Time-lagged Relationships

Habitual Dietary Intake
(3 weeks)

Physical Activity Expenditure
(8 weeks)

Starvation Response

When exposed to dramatically reduced caloric consumption, physiological systems will aggressively break down muscle tissue to reduce energy expenditure and will prioritize the storage and preservation of fat.

The Utility of

Energy Balance

Starvation Response

- If too large of an energy imbalance is created, physiological systems will become activated to actively work against the intended goals.
  - Energy systems will shift to aggressively break down muscle.
    - Muscle consumes a lot of energy
    - Breakdown of muscle will slow Metabolism
  - Energy systems will prioritize storage and preservation of fat.

The Utility of

Energy Balance

To Large of a Reduction Too Quickly

- Early research in this area suggested that these survival mechanisms were only brought online when calories consumed fell below 1.2x basal metabolic rate.
- Military research and evidence from famine/disaster conditions indicates that these survival mechanisms begin to be initiated when **energy deficiency reaches around 10 to 15% of habitual calories consumed** with more dramatic effects the larger the deficit.

The Utility of

Energy Balance

To Large of a Reduction Too Quickly

- Highly inconsistent dietary practices can also serve as a signal for physiological systems to activate starvation response strategies.
  - The system cannot tell if the inconsistency is intentional (dieting) or reflective of environmental issues in food availability.
- The World Health Organization requires food rations to provide at least 1,700 kcal per person per day.
  - Recommends 2,100 kcal per person per day

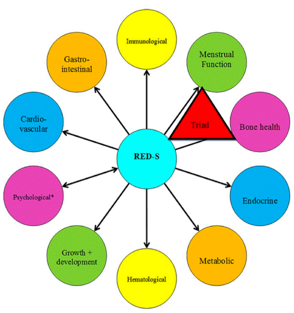
A Modern Focus on

Energy Deficiency

- NATO (North Atlantic Treaty Organization) allied militaries require:
  - Field rations to provide a minimum of 3,600 kilocalories per day
  - Recommends active combatants receive 4,200 to 4,800 kilocalories per day to compensate for the increased energetic expenditures.
  - When persistent energy deficits between dietary energy intake and energy expenditure occur, performance begins to degrade.
- Consequences of energy deficiency extend far beyond the 'female athlete triad'.

Relative Energy Deficiency Syndrome

An inadequacy of energy to support the range of body functions involved in optimal health and performance.



- Also known as Relative Energy Deficiency in Sport to highlight the negative influences on performance as well as health.
- This can manifest as
  - Chronic fatigue
  - Difficulty with concentration/coordination
  - Irritability (i.e., hangry)
  - Depression/anxiety
  - Difficulty adding muscle mass/size
  - Decreased training response
  - Reductions in endurance
  - Impaired judgement
  - Increased risk of injury

A Modern Focus on

Energy Deficiency

Energy Availability

$$\frac{\textit{Calories Consumed (kcal)} - \textit{Exercise Expenditure (kcal)}}{\textit{Fat Free Mass (kg)}}$$

Optimal Energy Availability
≥ 45 kcal/kg FFM provides adequate energy for all physiologic functions and maintenance of body mass.

Subclinical Low Energy Availability
30 to 45 kcal/kg FFM may be tolerated for short periods in well constructed body composition programs.

Clinical Low Energy Availability
< 30 kcal/kg FFM is high risk of impairment in health, detraining, and reduced performance.

A Modern Focus on

Energy Deficiency

- For athletes and military personnel engaged in excessive levels of physical activity at higher intensities, there is often not a strong biological imperative to match energy intake to activity-induced energy expenditure.
  - Appetite is not a reliable indicator of energy balance.
- For some sports, there is emphasis on keeping body mass as low as possible.
  - Potential concerns related to disordered eating.

A Modern Focus on

Energy Deficiency

- Highly-rigorous military training courses such as 'Ranger School' and special operations selection programs are often viewed as the pinnacle of elite training.
  - Nearly continual higher intensity, long duration physical exertion with minimal food intake.
  - Energy availability estimates for these courses place individuals at 12 kcal/kg FFM
    - Less than half the upper limit of clinically significant levels.

A Modern Focus on

Energy Deficiency

- The contexts of these courses/programs are well established at compromising the operational readiness of participants.
  - 15 to 30 lb reduction in fat-free mass
  - Reduction in strength and power of almost 20%
  - Following course/program completion, participants exhibit post-starvation symptoms.
    - Insatiable hunger
    - Rapid accumulation of adipose tissue
    - Prolonged slowing of metabolic rate