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## Brief Report

# Rethinking the Term "Energy Deficiency": A Critique of Oversimplification in Nutrition and Metabolism

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**Abstract:** This brief commentary challenges the use of the term "energy deficiency" in nutrition and metabolism, providing a critical examination of its scientific and philosophical aspects. It emphasizes the need to consider rare diseases associated with actual energy deficiency, which extend beyond the scope of everyday tiredness or fatigue. By analyzing energy balance and its complexities, this critique underscores the oversimplification associated with the term and its potential for misleading implications. It highlights the dynamic nature of energy metabolism and the intricate mechanisms involved in maintaining energy equilibrium, including the impact of rare genetic and physiological abnormalities. In addition to the discussion on energy balance, this commentary explores the manifestation of rare diseases that disrupt energy production, utilization, or hormonal regulation. Conditions such as mitochondrial diseases, glycogen storage diseases, adrenal insufficiency, and Prader-Willi syndrome are examined, shedding light on their profound impact on individuals' energy levels and overall health. The distinct time courses, underlying mechanisms, and clinical implications of protein deficiency, energy deficiency, and vitamin C deficiency are also compared, further emphasizing the complexity of energy metabolism and its relationship with various nutrient deficiencies. To foster a more comprehensive understanding of energy metabolism and enhance clarity in communication within the field, the commentary proposes the adoption of alternative terminology, such as "energy flux," to capture the multifaceted nature of energy balance more accurately. By reevaluating the terminology employed, researchers and healthcare professionals can better convey the intricate dynamics of energy metabolism and address the unique challenges faced by individuals with rare diseases causing actual energy deficiency. In conclusion, this commentary serves as a thought-provoking exploration of the concept of energy deficiency in nutrition and metabolism. It highlights the limitations of the term in capturing the complexities of energy balance, particularly in the context of rare diseases. By broadening the discussion to include these rare conditions, it encourages a more comprehensive understanding of energy metabolism and calls for precise and nuanced terminology to facilitate effective communication and advancements in the field.

**Keywords:** energy deficiency; energy balance; energy flux; terminology; mitochondrial diseases; glycogen storage diseases

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## Introduction

The term "energy deficiency" has long been used to describe an inadequate supply of energy in the context of nutrition and metabolism. However, this brief commentary challenges the validity and potential misleading implications of such a term. By exploring the dynamic nature of energy balance and considering both scientific and philosophical perspectives, this critique seeks to foster a more nuanced understanding of the complexities underlying energy metabolism.

## Scientific Critique

From a scientific standpoint, the critique posits that energy balance is a dynamic process influenced by individual variations, physical activity levels, and metabolic health. The use of the term "energy deficiency" oversimplifies this intricate system by reducing it to a binary state. Instead, acknowledging the body's ability to mobilize energy from its reserves, such as adipose tissue, during periods of reduced calorie intake is crucial for a more accurate representation of energy metabolism.

Furthermore, the concept of "energy deficiency" fails to account for the complexity of metabolic adaptations that occur in response to changes in energy intake. The human body is remarkably adept

at maintaining homeostasis and adjusting its energy expenditure in relation to energy availability [1]. Various physiological mechanisms, including changes in metabolic rate and hormonal signaling, come into play to regulate energy balance and ensure the body's energy needs are met.

By disregarding the intricate interplay between energy intake, energy expenditure, and metabolic adaptations, the term "energy deficiency" can perpetuate misconceptions about weight management and promote a simplistic view of the complex mechanisms involved. It is essential to recognize that energy balance is a dynamic and multifaceted process influenced by various factors, including nutrient composition, meal timing, genetic predisposition, and individual metabolic responses.

### **Philosophical Critique**

From a philosophical perspective, the critique challenges the application of the term "deficiency" to energy. Traditionally, deficiency implies a lack or insufficiency of a specific substance or nutrient necessary for bodily functions. Energy, however, is not a discrete substance, but rather an inherent aspect of life itself. By framing energy as a deficiency, the complex interplay of metabolic processes and the dynamic nature of energy balance may be overlooked.

Energy is a fundamental concept that encompasses the capacity to do work and sustain vital processes. It is intricately intertwined with various physiological functions, including cellular metabolism, tissue repair, and growth. Unlike specific nutrients or substances that can be deficient, energy is not a singular entity that can be lacking in isolation.

By adopting a terminology that portrays energy as deficient, we risk oversimplifying the intricate dynamics of energy metabolism and disregarding the holistic nature of human physiology. Energy balance involves a complex interplay between energy intake, expenditure, and storage, influenced by factors such as genetics, hormonal regulation, and environmental cues.

Furthermore, framing energy as a deficiency may inadvertently promote a reductionist perspective, emphasizing only the quantitative aspects of energy intake and expenditure, while neglecting the qualitative aspects. Energy is not solely about caloric quantities but also encompasses the nutrient composition, metabolic pathways, and physiological responses associated with energy utilization.

A more nuanced and philosophically robust approach would involve recognizing the dynamic nature of energy balance and appreciating the multifaceted interactions within the body's complex energy systems. This would enable a broader understanding of the intricate relationships between energy intake, expenditure, and overall health.

### **Vitamin C Deficiency vs. Energy Deficiency: A Clear Distinction**

To further underscore the critique, it is essential to compare the concept of energy deficiency with a well-established example of nutrient deficiency, such as vitamin C deficiency [2]. Vitamin C deficiency, also known as scurvy, is a condition caused by an insufficient intake of vitamin C over an extended period. The body's vitamin C stores gradually deplete, leading to overt symptoms of deficiency, including fatigue, weakened immune function, and impaired wound healing [2].

The key distinction between vitamin C deficiency and energy deficiency lies in the time course and the underlying mechanisms. In the case of vitamin C deficiency, it can take a significant period of time before individuals develop overt symptoms. This is because the body stores vitamin C to some extent, and it can take time for those stores to become depleted.

On the other hand, in the context of energy deficiency, the body has a more immediate response to inadequate energy intake. Unlike specific nutrient deficiencies, where the body's stores can act as a buffer, energy deficiency triggers dynamic metabolic processes that aim to maintain energy balance and meet the body's energy demands.

During periods of reduced energy intake, the body can mobilize energy from its stored reserves, such as fat tissue, to compensate for the temporary shortage. These adaptive mechanisms, involving hormonal regulation and metabolic adaptations, help ensure that essential physiological functions are sustained.

Therefore, while vitamin C deficiency requires a prolonged lack of vitamin C intake and depletion of the body's stores, energy deficiency is characterized by the body's immediate response to inadequate energy intake, involving the mobilization of energy from existing stores.

This distinction further supports the critique against the use of the term "energy deficiency" as it fails to account for the dynamic nature of energy balance and the body's inherent ability to adapt and utilize energy reserves.

### **Protein Deficiency vs. Energy Deficiency: A Comprehensive Comparison**

In order to expand upon the critique of oversimplification in nutrition and metabolism, it is important to examine the distinction between energy deficiency and another well-known nutrient deficiency, specifically protein (amino acid) deficiency. Protein deficiency occurs when there is an inadequate intake of essential amino acids, which are crucial for various physiological functions and the synthesis of proteins in the body [3].

While both protein deficiency and energy deficiency involve nutritional insufficiencies, there are significant differences in their impact on the body and underlying mechanisms. It is essential to explore these distinctions to gain a comprehensive understanding of the complexities involved.

#### *Physiological Functions*

**Protein Deficiency:** Inadequate intake of essential amino acids can impair the synthesis of proteins, which play crucial roles in tissue repair, enzyme production, immune function, and many other physiological processes.

**Energy Deficiency:** Inadequate energy intake affects overall energy balance, which is necessary for sustaining basic metabolic functions, physical activity, and cellular processes.

#### *Manifestation of Symptoms*

**Protein Deficiency:** Prolonged protein deficiency can lead to symptoms such as muscle wasting, delayed growth and development, weakened immune system, and impaired organ function.

**Energy Deficiency:** Inadequate energy intake can result in symptoms such as fatigue, weight loss, hormonal imbalances, and compromised organ function.

#### *Time Course and Body's Response*

**Protein Deficiency:** It may take a relatively longer time for overt symptoms of protein deficiency to manifest, as the body can initially rely on its protein stores for essential functions. However, prolonged deficiency can lead to serious health consequences.

**Energy Deficiency:** The body has a more immediate response to insufficient energy intake, triggering adaptive mechanisms to maintain energy balance, including mobilizing stored energy sources and conserving energy through metabolic adaptations.

#### *Adaptation and Recovery*

**Protein Deficiency:** Adequate protein intake, along with addressing the underlying cause of deficiency, is crucial for recovery and replenishing protein stores in the body.

**Energy Deficiency:** Meeting energy requirements through balanced nutrition and appropriate caloric intake is necessary for restoring energy balance and supporting overall well-being.

#### *Section Conclusion*

By examining the distinctions between protein (amino acid) deficiency and energy deficiency, it becomes evident that these conditions have unique implications for physiological functions, symptom manifestation, time course, and the body's response. Recognizing these differences is essential for accurate assessment, diagnosis, and appropriate intervention in the context of nutritional deficiencies.

### **The Abundance of Stored Energy: Challenging the Notion of Energy Deficiency as Lethal**

One of the key arguments against the concept of energy deficiency is the vast amount of stored energy available in the human body, even in individuals who may appear relatively thin. While energy deficiency might be presumed to be a lethal condition, the reality is that humans succumb to various causes long before energy depletion becomes a critical factor.

To illustrate the abundance of stored energy, let us consider a hypothetical scenario. Suppose we have an individual weighing 70 kilograms with a relatively low body fat percentage of 15%. Body fat is an energy-dense tissue, storing approximately 9 calories per gram. Given these values, this individual would have roughly 10 kilograms of stored body fat.

By performing a simple calculation, we can estimate the energy content of this stored fat mass. Since each gram of fat contains approximately 9 calories, the total energy stored within the fat mass would be approximately 90,000 calories (10,000 grams  $\times$  9 calories/gram). This means that even in a relatively lean individual, there is an extensive reserve of energy available.

Considering that a sedentary adult's daily energy requirement is typically around 2,000 to 2,500 calories, this stored fat mass could theoretically sustain this individual for 36 to 45 days without any additional caloric intake. These calculations demonstrate the significant energy stores that exist within the human body.

While energy deficiency might occur in specific circumstances, such as during prolonged starvation or severe malnutrition, it is crucial to recognize that humans are far more likely to succumb to other factors long before energy depletion becomes life-threatening. Diseases, infections, organ failures, and other critical health conditions are often the primary causes of mortality.

This perspective challenges the notion that energy deficiency, in isolation, is a lethal condition. The human body has evolved complex regulatory mechanisms to mobilize and utilize stored energy during times of reduced intake. This ability to adapt ensures that vital physiological functions can be sustained even in the absence of immediate energy supply.

By highlighting the massive amount of stored energy within the body, even in individuals who may appear relatively thin, we underscore the fact that energy deficiency, in and of itself, is not the primary cause of mortality. This recognition shifts the focus towards understanding and addressing the underlying health conditions that contribute to adverse outcomes.

### **Alignment with Widely Accepted Medical Definitions of Deficiency**

In the realm of medicine and nutrition, the concept of deficiency is commonly used to describe an insufficiency of specific substances or nutrients that are essential for optimal bodily function. Deficiencies in nutrients such as vitamins, minerals, and essential amino acids have been extensively studied and are well-established in medical literature [4]. When evaluating energy deficiency, it is crucial to examine how this concept aligns with these widely accepted definitions of deficiency.

Energy deficiency can be understood as a relative insufficiency of energy supply compared to the body's energy demands. Although energy is not a discrete substance like vitamins or minerals, it is a fundamental requirement for all physiological processes and activities. Just as a deficiency in a specific nutrient compromises normal bodily function, an inadequate supply of energy can have profound effects on health and well-being.

Energy deficiency can manifest in various forms, including insufficient energy intake, inadequate energy expenditure, or a combination of both. The consequences of energy deficiency can range from mild fatigue and impaired physical performance to severe metabolic disturbances and compromised organ function. In extreme cases, prolonged energy deficiency can lead to conditions such as malnutrition, wasting, and even death.

While energy deficiency might not fit the precise mold of deficiencies associated with specific nutrients, it can still be viewed within the broader context of insufficiency and impairment of essential physiological processes. Energy is a vital resource required for cellular metabolism, growth, repair, and overall homeostasis. In this sense, energy deficiency does align with the fundamental concept of insufficiency that underpins widely accepted medical definitions of deficiency.

It is essential to recognize that medical definitions and classifications are often tailored to specific contexts and substances. Deficiencies in vitamins or minerals, for example, are typically assessed based on established reference values and specific biochemical markers. In contrast, energy deficiency is a more complex and multifaceted concept that encompasses a dynamic balance between energy intake, expenditure, and storage.

By acknowledging the unique characteristics of energy as a resource and considering the context of energy metabolism, we can appreciate how energy deficiency aligns with widely accepted medical definitions of deficiency. While it may not conform precisely to the traditional notion of a nutrient



deficiency, energy deficiency shares common features such as impairment of bodily functions and adverse health outcomes.

### **Rare Diseases Causing Actual Energy Deficiency**

Rare diseases can cause genuine energy deficiencies that differ significantly from the transient feelings of fatigue or low energy levels experienced in everyday life. These conditions involve intrinsic abnormalities in energy production, utilization, or hormonal regulation, leading to chronic and profound energy deficits. In this chapter, we will explore four rare diseases known for causing actual energy deficiency and compare their manifestations to the more general concept of "energy deficiency."

#### *Mitochondrial Diseases*

Mitochondrial diseases encompass a diverse group of genetic disorders that affect the function of mitochondria, the energy-producing organelles within cells [5].

Manifestations:

- **Fatigue and exercise intolerance:** Individuals with mitochondrial diseases often experience persistent fatigue and an inability to sustain physical exertion due to impaired energy production.
- **Organ system involvement:** The lack of energy affects multiple organ systems, leading to a wide range of symptoms such as muscle weakness, neurological abnormalities, gastrointestinal issues, and cardiac dysfunction.

Comparison to "energy deficiency":

In mitochondrial diseases, the energy deficiency arises from fundamental defects in cellular energy production. The resulting symptoms go beyond temporary tiredness and encompass a broad spectrum of multi-organ dysfunction.

#### *Glycogen Storage Diseases*

Glycogen storage diseases (GSDs) are a group of inherited metabolic disorders characterized by abnormalities in glycogen metabolism, leading to impaired energy release from stored glycogen [6].

Manifestations:

- **Hypoglycemia:** GSDs can cause low blood sugar levels, leading to symptoms such as fatigue, weakness, and dizziness.
- **Hepatomegaly:** Enlargement of the liver is a common feature of GSDs and can contribute to reduced energy levels.
- **Muscle weakness:** Certain types of GSDs can affect muscle function, resulting in decreased energy and exercise intolerance.

Comparison to "energy deficiency":

In GSDs, the energy deficiency arises from the impaired breakdown and release of glycogen, the body's storage form of energy. This leads to specific symptoms related to low blood sugar, liver enlargement, and muscle weakness.

#### *Adrenal Insufficiency*

Adrenal insufficiency is a condition characterized by insufficient production or secretion of adrenal hormones, primarily cortisol and aldosterone [7].

Manifestations:

- **Chronic fatigue:** Individuals with adrenal insufficiency experience persistent fatigue and lack of energy due to hormonal imbalances.
- **Weakness and weight loss:** Muscle weakness and unintentional weight loss can occur as a result of adrenal insufficiency, further contributing to reduced energy levels.

Comparison to "energy deficiency":

Adrenal insufficiency disrupts the normal energy balance by affecting the production of crucial hormones involved in energy regulation. This leads to chronic fatigue, weakness, and weight loss that cannot be easily resolved through rest or lifestyle changes.

*Prader-Willi Syndrome*

Prader-Willi syndrome (PWS) is a rare genetic disorder associated with a range of physical, cognitive, and behavioral symptoms, including disturbances in energy regulation [8].

Manifestations:

- **Reduced muscle tone:** Individuals with PWS often have decreased muscle mass and weakness, contributing to decreased energy levels and physical stamina.
- **Obesity and metabolic abnormalities:** The insatiable appetite and slower metabolic rate associated with PWS can lead to obesity, which further exacerbates fatigue and reduced energy levels.
- **Hormonal imbalances:** PWS is characterized by hormonal deficiencies, including growth hormone deficiency and sex hormone abnormalities, which can impact energy regulation.

Comparison to "energy deficiency":

In the context of Prader-Willi syndrome, the energy deficiency arises from a combination of factors, including reduced muscle tone, metabolic disturbances, and hormonal imbalances. These collectively contribute to a state of genuine energy deficiency in individuals with PWS.

*Section Conclusion*

Rare diseases causing actual energy deficiency present a stark contrast to the more general concept of "energy deficiency. While everyday feelings of fatigue or low energy can often be resolved through rest, lifestyle changes, or addressing temporary factors, rare diseases involving energy deficiency stem from underlying genetic or physiological abnormalities. Conditions like mitochondrial diseases, glycogen storage diseases, adrenal insufficiency, and Prader-Willi syndrome disrupt energy production, utilization, or hormonal regulation, leading to chronic and profound energy deficits.

Comparing these rare diseases to the concept of "energy deficiency" experienced in everyday life, it becomes evident that the underlying mechanisms and manifestations differ significantly. Rare diseases causing energy deficiency involve fundamental defects in cellular energy production, glycogen metabolism, adrenal hormone production, or energy regulation pathways. These abnormalities lead to persistent and debilitating symptoms that cannot be easily resolved through temporary measures.

**Revisiting the Terminology Debate**

The ongoing debate surrounding the terminology of "energy deficiency" raises important questions about the appropriateness and implications of such language in the context of nutrition and metabolism. While the previous sections have discussed the limitations and potential inaccuracies of using the term "energy deficiency," it is worth exploring this topic further to gain a comprehensive understanding of the arguments and considerations involved.

*The Complexities of Energy Balance*

Energy balance is a dynamic and multifaceted process influenced by various factors, including individual variations, physical activity levels, and metabolic health. The concept of energy deficiency fails to capture the intricate interplay between energy intake, expenditure, and storage. By reducing energy balance to a binary state of deficiency or sufficiency, we risk oversimplifying the complexities involved in maintaining optimal energy equilibrium.

*Shift in Focus*

Critics of the term "energy deficiency" argue for a shift in focus from deficiency to a broader understanding of energy dynamics. By adopting alternative terminology, such as "energy flux," researchers and practitioners can better capture the dynamic nature of energy balance. This shift in perspective encourages a more comprehensive examination of energy intake, expenditure, and storage over time, considering the qualitative aspects related to metabolic pathways, energy utilization, and adaptive responses.

### *Misleading Implications*

The use of the term "energy deficiency" may inadvertently promote misleading implications, particularly regarding weight management and body composition. It may reinforce the misconception that energy deficiency alone is responsible for weight loss or that an individual's body weight accurately reflects their energy status. By neglecting the complex interplay between energy intake, expenditure, and metabolic adaptations, this terminology may perpetuate oversimplifications and hinder a holistic understanding of weight regulation.

### *Energy Storage Capacity*

One aspect often overlooked in the discussion is the vast amount of energy stored within the body, even in individuals who may appear relatively thin. Adipose tissue, for instance, serves as a substantial energy reservoir, capable of providing energy during periods of reduced calorie intake. By highlighting the significant energy stores within the body, we can challenge the notion that individuals primarily die due to energy deficiency. Instead, it becomes evident that other factors, such as specific nutrient deficiencies or organ failure, may be the primary cause of mortality in these cases.

### *Implications for Clinical Practice*

Reevaluating the terminology used in the context of energy deficiency has implications for clinical practice. It encourages healthcare professionals to consider a broader range of factors influencing energy balance, including nutrient composition, meal timing, genetic predisposition, and individual metabolic responses. This comprehensive approach can lead to more personalized and effective interventions for patients.

### **Exploring Alternative Terminology**

This critique proposes the exploration of alternative terminology that better captures the nuanced nature of energy balance. Concepts such as "energy flux" [9,10,11], which emphasizes the dynamic interplay of energy intake, expenditure, and storage, may provide a more accurate representation of the complexities involved. Shifting the focus from deficiency to a broader understanding of energy dynamics could lead to improved comprehension and communication within the field of nutrition and metabolism.

The term "energy flux" highlights the continuous flow and exchange of energy within the body. It recognizes that energy balance is not a static equilibrium but rather a dynamic process influenced by various factors. Energy flux encompasses not only the quantitative aspects of energy intake and expenditure but also the qualitative aspects related to metabolic pathways, energy utilization, and adaptive responses.

By adopting terminology that emphasizes energy flux, researchers and practitioners can better capture the intricate nature of energy balance. This broader conceptual framework encourages a holistic approach to studying and understanding energy metabolism, encompassing the interplay between energy intake, expenditure, and storage over time.

Moreover, the use of alternative terminology can promote clearer and more precise communication within the field. It enables researchers, clinicians, and individuals interested in nutrition and metabolism to engage in discussions that reflect the complexities of energy dynamics. This shift in terminology could enhance interdisciplinary collaboration, facilitate the exchange of knowledge and ideas, and foster a more comprehensive understanding of the factors influencing energy balance.

### **Conclusion**

In conclusion, the term "energy deficiency" has long been used to describe inadequate energy supply within the field of nutrition and metabolism. However, this critique challenges the inherent oversimplification of the term and highlights the dynamic and multifaceted nature of energy balance. By considering both scientific and philosophical perspectives, we can achieve a more nuanced understanding of energy metabolism and its implications.



From a scientific standpoint, the critique emphasizes the dynamic nature of energy balance, influenced by individual variations, physical activity levels, and metabolic health. The term "energy deficiency" fails to capture the complexity of this intricate system, which involves the mobilization of energy from reserves during periods of reduced calorie intake. Recognizing the body's ability to adapt and utilize energy stores provides a more accurate representation of energy metabolism.

From a philosophical perspective, the critique challenges the application of the term "deficiency" to energy itself. Energy is not a discrete substance but an inherent aspect of life. By framing energy as a deficiency, we overlook the complex interplay of metabolic processes and the dynamic nature of energy balance. This reductionist view fails to capture the full scope of energy's role in human physiology.

To advance our understanding of energy metabolism, it is proposed to explore alternative terminology that better captures the nuances of energy balance. Concepts such as "energy flux" highlight the dynamic interplay of energy intake, expenditure, and storage over time. Shifting our focus to a broader understanding of energy dynamics can lead to improved comprehension and communication within the field of nutrition and metabolism.

In summary, this critique challenges the oversimplification of the term "energy deficiency" and advocates for a more comprehensive and nuanced understanding of energy balance. Exploring alternative terminology that captures the complexity of energy metabolism can enhance our comprehension of this vital aspect of human physiology. By considering both scientific and philosophical perspectives, we can pave the way for a more accurate and comprehensive discourse on energy balance and its implications for human health and well-being.

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