

Underweight, the Less Discussed Type of Unhealthy Weight and Its Implications: A Review

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Abstract

Underweight is body weight that is too low for a normal healthy adult or child. It is also known by various other names such as wasting, emaciation, thinness, stunting, etc., and is caused by multiple factors especially lack of adequate nutrients in the body. This type of unhealthy weight is not much publicized in developed wealthy countries because it is not very common except under extreme circumstances like some sick geriatric populations, disabled people, chronic diseases sufferers, the homeless people, refugees, and people afflicted by wars and natural disasters. The discussion about underweight in developed countries seems to be drowned by the chorus on concerns for the obesity epidemic and its consequences as well as the risks of excessive consumption of calories. However underweight is a front burner issue in some developing poor countries where it is a recognized perennial problem that has led to negative health consequences and sometimes death of preschool children, pregnant and lactating mothers as well as very sick, disabled or aged people. Public health professionals as well as nutritionists, social workers, clinicians and educators need to be skilled in recognizing underweight and its implications on health and wellness. Such skills are necessary in order to effectively counsel consumers & patients on food choices and weight management or to give appropriate referrals to affected individuals to enable them get expert help on maintaining healthy weight. This paper will define what is meant by underweight, with real life examples. Using data from published studies, the paper will discuss consequences and causes of underweight and how caloric intake impacts body weight. It will also highlight and re-emphasize the benefits of adequate caloric intake and healthy weight. Strategies for improving underweight and maintaining adequate body weight for good health and wellness are suggested.

Keywords

Underweight, Emaciation, Stunting, Causes, Consequences, Weight Restoration, Caloric Intake, Health & Wellness

1. Introduction

Underweight is described as body weight that is too low to be considered healthy for a normal adult, adolescent or a child. It can also occur in the elderly. In street language, an underweight adult is called by many names or descriptions such as 'skinny', 'emaciated', 'thin', 'bony structured' or 'lanky'. Such an adult may also be called 'super slim', 'flat-chest', 'lightweight', 'lean', 'feather', 'super slender', etc. A child who is underweight is sometimes called in the layman's language with names such as 'teeny-weeny child', 'tiny child', 'tiny-Tom', 'tiny-Tina' or said to have stunting, thinness and wasting. Such a child is sometimes described by

nutritionists as being short-for-age, low weight-for-age or low weight-for-height.

Underweight can also be described clinically as low BMI-for-age, where BMI (body mass index) is calculated in the metric system [1] as a person's weight in kilograms (Kg) divided by the height in meter squared (m^2). (In the metric system equation, $BMI = Kg/m^2$). In the imperial system, BMI is calculated as a person's weight in pounds (lb) divided by the height in inches squared (in^2), and the result is multiplied by a factor, 703, to get the BMI score [1]. (In the imperial system equation, $BMI = \{lb/in^2\} \times 703$).

Underweight, stunting, wasting and overweight are indicators of malnutrition and impact child growth. Child growth is well recognized as a very important indicator of

nutritional status of any population group or any country.

1.1. Unhealthy Weights as Indicators of Malnutrition and Their Measurement

Underweight (including stunting and wasting), as well as obesity and overweight are different forms of unhealthy weight that result in malnutrition. Each form of unhealthy weight has different clinical measurements as well as many causes and health consequences.

1.2. Underweight Determinations

Underweight is determined differently in adults, the elderly and children of various ages.

i. Underweight Determination in Adults and the Elderly

In adults and the elderly, underweight is defined as BMI less than 18.5 [1]. Underweight is also a term used to describe adults who are 15% to 20% or more below their usual or ideal body weights [2]. Other nutritionists use the term 'underweight' to describe people experiencing unintentional weight loss [2], [3].

ii. Underweight Determination in Children Aged Two Years or More

In children aged two years or more, underweight is defined clinically by the Center for Disease Control and Prevention (CDC) growth chart established in 2000 [4] as BMI-for-age less than the 5th percentile; sometimes an underweight child may also have a short stature or stunting. The CDC chart [4] defines short stature as height-for-age less than the 5th percentile.

iii. Underweight Determination in Children Aged Less than Two Years

In children aged less than two years, the World Health Organization (WHO) growth chart of 2006 [5] is applied in determining underweight, and it defines underweight as weight-for-length less than or equal to the 2.3rd percentile; the WHO chart [5] also defines short stature in that age group as length-for-age percentile less than or equal to the 2.3rd. Underweight children who experience stunting or wasting may have chronic under nutrition arising from many causes including food shortages, illnesses and other factors. Underweight in children is sometimes called low weight-for-age. It can include both stunting and wasting [4]-[6].

iv. Description and Measurement of Stunting

Children who have stunting are described as being short-for-age or as having low height-for-age, growth retardation or short stature. The stunted child may look too young for the declared age. Stunting in children can result from both under-nutrition and infections and is an indicator of poor environment, inadequate nutrition and an extended restriction of a child's growth. Some consequences of stunting in a child include delayed mental development, poor academic performance and decreased cognitive capacity. A country with a large number of intellectually less developed children

is at a disadvantage as this situation can persist until adulthood. Intellectually less developed adults can affect the quality of a country's national workforce, work productivity and its economic development according to the WHO [6].

Women of short stature tended to have smaller pelvis which might impact labor and delivery. Smaller pelvis might also increase risk of obstetric complications [6]. Such women with short stature also tended to have low birth weight infants, preterm infants or infants with intra-uterine growth retardation. Infants born to short statured women may grow up to be small adults if they received no early interventions and will repeat the cycle all over again when they get pregnant and start having children of their own. Thus children of short statured mothers may also turn out to be underweight and stunted.

According to the WHO [6], if a child's height-for-age is more than 2 standard deviations below the WHO standard, then the child is said to have stunted growth, and may be underweight and /or undernourished. However not all stunted children are undernourished. Stunting is caused by many other factors including genetics, environment, inadequate protein and calorie intake, chronic caloric deficit, stress and chronic infections like malaria, parasitic infections, various diseases etc.

v. Description and Measurement of Wasting

Wasting is described as low weight-for-height or emaciation. If a child's weight-for-height index is more than 2 standard deviations below the WHO [6] standard, then the child is said to have wasting, and may be underweight and undernourished [6], [7]. Unlike stunting, wasting is a stronger indicator of malnutrition in a child. Wasting is caused by severe caloric deficit, diarrhea, and dehydration, excessive loss of body fat and loss of muscle tissue. Wasting can be reversed with gradual controlled replenishment of nutritious food, supplements and beverages while treating any underlying illnesses and infections. Wasting can also impair the immune system and can increase susceptibility to infections, thereby increasing length of hospital stay and hospital cost as well as readmission rates.

1.3 Forms of Unhealthy Weight

Various forms of unhealthy weight have their BMI cut offs and classifications. They also have various health consequences.

1.3.1. Obesity as a Form of Unhealthy Weight

A body mass index (BMI) value of 30.0 or above is described as obesity and it has many health consequences [1], [8]. Obesity is further categorized as class I or mild obesity (BMI at 30.0-34.9), class II or moderate obesity (BMI at 35.0-39.9) & class III or extreme /morbid obesity (BMI at 40.0 and above) [1]. In Asian populations, obesity cut off points are lower. Asians have a higher tendency to develop metabolic syndrome, so their BMI cut off for obesity is revised downwards to 25 instead of 30.0 according to published reports [9]. A simple way of estimating obesity in

a community or rural setting is to measure the waist circumference with a tape measure as described later; a waist circumference greater than 35 inches in women or greater than 40 inches in men is indicative of obesity.

Obesity has reached epidemic proportions in the United States of America (USA) [10], [11] and other countries [12]-[14] including developing countries [15]-[17]. Obesity has several causes, some of which are obvious while others are hidden [18]. Several efforts have therefore been made in curbing obesity epidemic both in the USA [19]-[21] and other parts of the world [17]. Despite the obesity epidemic, some segments of the US population especially geriatric and/or very sick or disabled populations suffer from underweight and inadequate weight gain [22]. Similarly, people in some developed parts of the world [23] and some developing countries [16] experience underweight, overweight and obesity in various segments of their populations.

1.3.2. Overweight as a Form of Unhealthy Weight

In many populations, overweight is described as a BMI value between 25.0 and 29.9 [1]. For Asians, overweight is described as a BMI value between 23.0 and 24.9 [9]. There are other methods of estimating overweight in the field and community settings. Such methods involve using a simple tape measure to measure waist circumference (WC), hip circumference (HC) & a person's height (Ht) in an upright position. From these measurements, one can calculate the waist-to-hip ratio (WHR) & waist-to-height ratio (WHtR). Both WC, WHR, are good estimates of fat distribution in the body according to the World Health Organization [24] and high WHR correlates positively with many metabolic diseases such as Type 2 Diabetes mellitus (T2DM), stroke, infertility, hypertension & cardiovascular diseases [24]. Anecdotal reports however claim that low WHR is directly correlated with fertility and female attractiveness. Waist circumference is the measurement of distance round the abdomen just above the belly button while hip circumference is distance round the hip through the widest part of the buttocks. Waist-to-hip ratio (WHR) is the ratio of waist circumference (WC) to the hip circumference (HC). (Thus $WHR = WC/HC$). Both WC & HC must be measured in the same units before deriving the ratio (WHR). If the waist to hip ratio is greater than 0.9 in men, or greater than 0.8 in women, it is indicative of overweight and obesity and high risk of metabolic diseases. High WHR and WC correlated positively with high rates of overweight and obesity as well as higher risk of cardio-metabolic diseases.

The waist-to-height ratio (WHtR) is another good estimate of fat distribution in the body. The WHtR is the ratio of waist circumference to height, both measured in same units. (Thus $WHtR = WC/Ht$). The WHtR can be used to estimate overweight and obesity and predict risk of metabolic diseases better than BMI according to recent reports [25]. If the WHtR is less than 0.50, it is indicative of low risk of metabolic diseases. If the ratio is around 0.50 or higher than

0.50, it indicates overweight and obesity and increased risk of metabolic diseases like T2DM, stroke, infertility, CVD and others. Recent studies indicate that keeping WHtR below 0.50 (i.e. keeping a person's waist circumference at less than half of the person's height) is one good way of reducing risk of metabolic disease and increasing life expectancy [25].

Overweight is very common in many developed countries and some developing countries where overweight can coexist with obesity and underweight [8], [13], [16]. If overweight in an adult is not well controlled by physical activity, behavior modification and diet, it can result into obesity. Similarly an overweight child without early intervention to control excess weight can grow up living with overweight and obesity and these conditions may continue into adulthood. Adult obesity can have many consequences such as diabetes, hypertension, cardiovascular and other diseases [8] as stated above.

1.3.3. Underweight as a Form of Unhealthy Weight

Underweight in an adult is described as a BMI value less than 18.5 [1]. Underweight does occur in some segments of populations in some developed countries, but it is not very common in the USA. Underweight however has been a perennial problem of many developing countries and is a result of many causes including diarrhea, poor sanitation and hunger [7]. It is however ironic that underweight, diet-related anemia and obesity can coexist in the same country, but in different segments of the populations in both developed and developing regions of the world [13], [16], [18], [22], [23].

1.4. Global Hunger, Under-nutrition & Unhealthy Weight

The issue of world hunger has been acute and has been recognized as very problematic by several world bodies including the United Nations (UN), World Health Organization (WHO), World Health Assembly Health Ministers, Food and Agricultural Organization (FAO) and United Nations Children's Emergency Fund (UNICEF). The United Nations made hunger a front burner issue and one of the most important goals of the Millennium Development Goals (MDGs) established in the year 2000 at the Millennium Summit of World Leaders [26]. In that summit, world leaders resolved to set targets for overcoming not only hunger but also income poverty, diseases and other shortcomings. Although few countries experience overt starvation and acute hunger due to wars, natural disasters and famine, many countries especially developing countries suffer sporadic food shortages, chronic food insecurity and chronic under-nutrition. Some segments of the populations in developing countries are therefore chronically underweight. In some developed countries, a few segments of their populations (especially the elderly and the homeless) experience food insecurity [27], while other communities designated as 'food deserts' lack nutritious and affordable foods or means of obtaining fresh foods [28]. Eradication of extreme hunger and poverty by 2015 was some of these UN Millennium Development Goals that

needed to be achieved [26].

As described above, it is obvious that so many forms of unhealthy weight (obesity, overweight & underweight) exist. This paper will focus mainly on underweight as a form of unhealthy weight. It will also review the consequences and causes of underweight and will discuss strategies for maintaining healthy weight in many populations.

2. Discussions

2.1. Consequences of Underweight

2.1.1. General Consequences of Underweight and Inadequate Caloric Intake

Inadequate caloric intake leads to inadequate weight gain and underweight which may lead to many problems [22], especially if the inadequate food intake is sustained for a long period of time. The negative consequences of inadequate food intake and underweight can be observed in all age groups, from infants and children, to adolescents, women of child bearing age, adults and elderly populations (Table 1).

Table 1. General Consequences of Underweight in Various Population Groups.

Consequences of Underweight	References
Inhibited growth and development in form of stunting and wasting in children	[29]-[35]
Low lean body mass or low muscle mass	[36],[37]
Failure to thrive and developmental delays in children	[38], [39].
Weakened or compromised immune system that makes a person prone to infections	[40]-[44]
Fragile bones, fracture s and osteoporosis	[45]-[49]
Frailty in older adults	[50]
Anémia	[27], [51], [52]
Vitamin deficiencies in normal and sickle cell patients	[7], [52]-[54]
Fertility issues such as amenorrhea, failed conception & pregnancy complications	[55]-[59]
Poor pregnancy outcomes	[60]
Disrupted hormone regulation and menstruation problems	[61]
Hair loss & hair thinning	[58], [62], [63]
Poor ingestion, digestion, absorption and assimilation of food that result in frailty	[54], [64]
Chronic and general fatigue, heart rhythm problems, low energy, weakness and dizziness	[65]-[67]
Hypothermia	[68]
Hypoglycemia	[69]
Burns that take long time to heal	[70]
Poor wound healing & pressure ulcers	[70],[71]
Chronic diseases	[72]
Psychological issues such as poor self image, lack of self confidence, self esteem issues and stress	[67], [73]
Bad mood and unexplained anger or aggression due to hunger	[74]
Poor self-control	[75]
Poor sleep and stress	[76]
Relative energy deficiency in sports(RED-S) & female athletic triad	[77], [78]
Increased mortality	[78]-[83]

2.1.2. Consequences of Underweight in the Elderly and Adults

Underweight and malnutrition are more common in the elderly population than other adult population groups and has many causes and consequences [84]. Some consequences of underweight and under-nutrition especially in the elderly include decline in functional status, impaired muscle function, decreased immune function and reduced cognitive function [85]. Other consequences of underweight include decreased muscle mass, sarcopenia, decreased bone mass, skeletal disorders, weight loss, anemia; poor wound healing and pressure ulcers as listed in Table 1. Some underweight consequences in the elderly also include delayed recovery from surgery, longer length of hospital stay, higher hospital cost and higher readmission rates [85].

2.1.3. Consequences of Underweight During & After Pregnancy in Women of Child Bearing Age

One of the serious consequences of underweight is poor health in a pregnant or breastfeeding mother. Underweight is more common in women than in men in some communities in developing countries [86]. Poor diet during and after pregnancy can result in underweight and poor health in the woman and her child [60]. Poor diet is caused by inadequate food and beverage intake, chronic food shortage, food insecurity, lack of nutritious food and drink, chronic hunger and starvation. Although underweight affects all population age groups (adolescent, adult man/ woman and the elderly), and occurs more commonly in the elderly, it has very serious consequences when it occurs in pregnant and breastfeeding women or in infants and children.

Extreme underweight can negatively impact the health of both a pregnant undernourished woman and that of the unborn child in the womb. Such a woman can have complications in pregnancy and delivery [55], [56], [59] & [60]. An underweight pregnant mother can deliver premature or preterm baby, and/ or low birth weight infant or an infant described as ‘small for gestational age’ [60]. The infant of an undernourished pregnant woman may be born underweight, and may develop malnutrition, stunting or wasting and/or decreased mental and physical capacities [60]. A chronically undernourished and underweight woman may not be capable of making enough breast milk to feed her baby or to rebuild her body tissues following delivery; she may also not be able to replenish all blood lost during child birth. An undernourished and underweight woman may easily succumb to fatigue and diseases and may be unable to meet the energy demands of caring for her newborn baby or other children in her family. Such a woman may be prone to anemia, weakness and various infections which can lead to increased maternal illness and even mortality [60].

2.1.4. Malnutrition and Underweight as a Result of Poor Food Intake in Children

A child who is not well fed, will start displaying poor nutritional symptoms within six months or less, and can succumb to underweight; such a child may develop malnutrition which can lead to appetite loss. A chronically

hungry underweight child that developed under-nutrition at the critical period of brain development (from pregnancy & birth to preschool) may become physically and cognitively impaired and not functional unless there is an early intervention to improve nutrition and health of the child [87]-[91].

2.2. Caloric Intake, Storage and Bodyweight

Caloric intake affects caloric storage and body weight. Inadequate caloric storage occurs when energy expenditures (through exercise, physical activity or metabolism) exceed energy intake (through food, supplements and drinks), and can result in weight loss, malnutrition, underweight and other problems. In extreme cases, underweight can lead to chronic diseases and death [79] - [82]. Inadequate caloric intake has many consequences and causes as observed in children, adults and the elderly [29], [73], [83], [85], [93].

2.3. Major Factors Causing Inadequate Calorie Intake and Underweight

Many factors cause underweight in children, adults, women and the elderly and sometimes result in both morbidity and mortality at national, regional and global levels. A list of some possible factors that cause underweight is shown in Table 2a and will be discussed thereafter.

Table 2a. Major Factors that Cause Underweight

Major Factors that Cause Underweight	References
Poor food intake	[94], [95];
Insufficient food intake	[36], [94]-[96]
Difficulty chewing or swallowing	[[97];
Loss of teeth, gum & denture problems	[97];
Age related issues: mobility issues & difficulties in tasting, smelling & eating of food	[98]
Loss of appetite	[85], [98], [99];
Loss of sense of taste /smell	[99];
Lack of motivation to cook or eat out	[24],[25],[98]
Parasitic or helminthes infections e.g. amebiasis, round worms, malaria, hookworms, giardiasis,	[40]-[43], [52],
Bacterial infections, urinary tract infections (UTI), pneumonia, E. coli, Staphylococcus & Salmonella infections.	[100]-[102];
Irritable bowel diseases	[40], [41], [43], [44].
Malnutrition and deficiencies of vitamins/minerals ;	[22]
Being put on 'NPO' ('Nothing by Mouth') for a long period of time while preparing for surgery or lab tests.	[7], [103];
Use of Stimulant /appetite suppressing drugs	[22], [23], [98].
Voluntary consumption of fad diets	[136]-[139]
Food allergies and food intolerances	[140];
Lifestyle and social factors (such as poverty, poor socialization, loneliness, Inabilities to shop, prepare, cook and store food; lack of knowledge of nutritious food and their functions in body.	[141], [142]
Environmental factors such as	
- limited food choice and variety while in hospital,	
-poor texture, flavor and appearance of food, poor food quality,	
-dependent on assistance to feed self,	[72], [118]-[121]
-inability to reach food, hold cutlery or open packages,	
-temperature of food not adequate, unpleasant sight, sound, or smell of food or unpleasant food environment.	

Major Factors that Cause Underweight	References
Limited cultural, ethnic or religious foods available to choose from	[24],[25], [98]
Orphans & vulnerable children (OVC)	[122], [123]
Fatigue and emotional factors	[65], [67], [76]
Burns, pressure ulcers, immobility and chronic pain	[22], [54],[98];
	[22], [37], [48],
	[49], [50], [54],
Old age and related issues	[85], [98], [103],
	[124], [145]-
	[151].

Table 2b. Other Factors that Cause Underweight

Other Factors that Cause Underweight	References
Side effects of some medications;	[3], [98],
Cancer medications	[104], [105];
	[3], [98],
	[104],[105]
Anorexia, bulimia, eating disorders	[28], [29],
Fatigue, Over-exercising or over-training	[93];
	[65], [67],
	[76]; [77],
	[78].
Underlying illnesses	[22], [54],
	[98]
Chronic & Wasting diseases e.g.	[22], [113]
Lou Gehrig's disease & Multiple sclerosis or MS;	[114]-[116];
Tuberculosis or TB	[129], [130],
Cancer, Pancreatitis, Cystic fibrosis,	[131];
HIV/AIDS (Human Immunodeficiency Virus/Acquired Immune Deficiency Syndrome),	[132];
Other diseases & viral infections such as Ebola, Zika	[132]-[135];
Organic diseases	[22].
High basal metabolic rate or BMR ;	[110]-[112];
Hyper-active thyroid	[110]-[112].
Lower Gastro Intestinal (GI) problems e.g. cancer of intestine, irritable bowel disease, pancreatitis,	[40], [44],
appendicitis, that result in mal-absorption, tube feeding	[103];
Diarrhea, nausea, vomiting	[40]-[44]
Upper GI problems e.g. cancer of mouth, tongue, pharynx, esophagus, stomach, that result in tube feeding	[40], [44],
Genetics (some people inherit lean or skinny genes)	103].
Psychosocial, economic & political problems:	[108], [109],
Trauma, fear, violence, bereavement	[106], [107];
Refugee/migrant status	[106], [127];
Psychological factors like confusion, dementia,	106], [107];
depression, bereavement anxiety and even paranoia;	[106], [107];
Stress, anxiety, depression	
Toxic or unsafe drinking and cooking water	[126]
Smoking	[103], [143],
	[144]
Excess Alcohol intake	153
Hunger suppressing herbs such as 'khat'	[154]-[157]

2.3.1. Poor Food Intake in Children

A child must be well fed with breast milk or formula to grow and develop well. There are many causes of underweight in small children, and most of these causes can lead to death [94], [95]. These causes include:

- Not feeding a child with breast milk or formula;
- Irregular feeding of child with breast milk or formula;
- Food rationing for a young child;
- Early feeding of solid foods while withholding breast milk and formula;
- Lack of nutrient dense foods;

- Lack of essential nutrients (such as essential amino acids, essential fatty acids, critical vitamins and minerals) in food given to child;

- Insufficient food fed to the infant irregularly;

- Poor feeding practices;

- Non-exposure of child to adequate sunlight to make vitamin D necessary for proper bone development;

- Early introduction of child to weaning and complementary foods that consist of cultural adult foods (such as tea, high fiber foods) containing anti-nutrients (phytates, tannins) that decrease absorption of vitamins and minerals;

2.3.2. Insufficient Food Intake and Poor Diet in Adults and the Elderly

Poor diet can be a result of several factors such as: inadequate food and beverage intake, lack of available food and drink, chronic food shortage, chronic hunger, starvation and food insecurity. People who eat infrequently, or those who do not eat at all, or people who do not consume enough nutritious food and beverages easily become underweight. Such people do not get energy to function and live their lives fully and actively. Consequently their weight progressively decreases and they eventually become malnourished and severely underweight [36]. Underweight due to poor diet can occur in men or women. An underweight man or woman is not strong enough to perform physical and mental activities expected of a normal man or woman of same age [94]-[96].

2.3.3. Refugee and Migrant Status

In the case of refugees, migrants and children fleeing war zones and natural disasters, they are under a lot of stress. Such stress arising from moving from their familiar towns and villages to unfamiliar cities in other countries with different lifestyles and food habits can lead to underweight and malnutrition [106], [127].

2.3.4. Orphans and Vulnerable Children

In the case of children orphaned by AIDS, infectious diseases or other environmental factors, stress from transitioning from birth mother to adoptive mother or care giver can affect food intake and cause underweight and malnutrition [122], [123].

2.3.5. Voluntary Consumption of Fad Diets

Some people especially adolescents follow certain fad diets because such diets are in vogue or because of peer pressure. Others follow fad diets if such diets were recommended by friends as a way to manage weight. Some fad diets are very restrictive in the type and quantity of food eaten or in their nutrient content. Following strict fad diets tend to result in under-nutrition and underweight [140].

2.3.6. Underweight Causes in the Elderly

i. Old Age & Related Issues

Some people especially the elderly are underweight because of age related factors. An extensive review by Hickson [98] showed that factors that cause underweight and

malnutrition in the elderly can be grouped into medical, lifestyle, social factors as well as psychological and environmental factors. Other risk factors that affect underweight and malnutrition in the elderly include weight loss caused by wasting, sarcopenia and cachexia as well as, mobility issues [54], [145]. Some older people become underweight because of sarcopenia due to not exercising their muscles [37], [50].

Underweight in the elderly is also caused by difficulty tasting, chewing or swallowing food and loss of teeth [146], lack of motivation to cook or eat outside the home [22], poverty due to diminished income at retirement that makes it difficult for the elderly to purchase nutritious food; other factors contributing to underweight in the elderly population include social isolation and loss of appetite [22, 54, 124]. Some elderly people do not remember to eat and drink because of senile dementia and Alzheimer's disease hence they become underweight and sometimes get dehydrated [147].

Other elderly people have decreased gastro-intestinal (GI) motility and decreased GI function as a result of aging and this can lead to poor absorption and sometimes constipation [98], [103], [148]-150]. Some elderly people have small bowel bacterial overgrowth and consequently not able to absorb nutrients efficiently from food and this also contributes to underweight [54], [151]. Many elderly people become underweight because they are no longer able to make tissue building anabolic hormones like growth hormone and sex hormones because of aging [54], [85] & [103].

ii. Fatigue and Emotional Factors

Some people are underweight because of fatigue and emotional issues such as stress, anxiety and depression [65], [67] & [76].

iii. Poor Mastication of Food & Loss of Senses of Smell & Taste

The loss of teeth leads to poor food mastication and decreased food intake which can result in underweight. Similarly loss of sense of taste and problems with upper gastro-intestinal (GI) tract such as cancer of the mouth, tongue, pharynx, esophagus, stomach, stroke and general GI malfunction can lead to decreased food intake, resulting in underweight in both young and old people [54], [99], [110], [146] & [152].

iv. Loss of Appetite

Loss of appetite reduces amount of food consumed, can lead to food aversion and results in decreased food intake, weight loss and underweight [85], [98] & [99].

2.3.7. Parasitic Infestation

Underweight and weight loss can be caused by parasites (insects, fungi, viruses and helminthes or parasitic worms) that attack an individual's body especially in some developing regions of the world as well as some developed countries. These parasites tend to infect various body systems including the cardiovascular and gastrointestinal systems,

resulting in poor food intake, poor absorption and utilization of the consumed food, leading to weight loss, anemia and underweight [40], [41], [43], [52], [100]-[102].

2.3.8. Bacterial Food Infection and Food Poisoning

Food poisoning can cause underweight. This is due to excessive diarrhea, loss of electrolytes, nausea and vomiting from food poisoning. Underweight can also result from deficiencies of digestive enzymes & stomach acid. In addition, bacterial & viral infections that affect the gastro-intestinal tract can also cause underweight [40], [41], [43], and [44].

2.3.9. Food Allergies and Food Intolerances

Hidden food allergies like gluten, soy and milk allergies or intolerances for lactose and gluten can lead to mal-absorption of nutrients and result in underweight especially in children [141, 142].

2.3.10. Mineral and Vitamin Deficiencies

Malnutrition especially deficiencies of minerals and vitamins as well as deficiencies of essential nutrients also cause underweight [7], [103].

2.4. Other Factors Causing Inadequate Calorie Intake and Underweight

Other factors mainly medical, genetic, behavioral, economic and psycho-social problems also contribute to causing underweight as listed in Table 2b; these are discussed below.

2.4.1. Medications

Sometimes underweight is caused by food-drug interactions or drug-drug interactions that affect food intake and body weight or cause bleeding problems. Underweight could also be due to side effects of medications, that decrease appetite or induce vomiting and diarrhea [104], [105]. Some stimulant medications used in treating attention deficit disorders are known to cause weight loss and/or underweight [3]. Sometimes drug-drug interactions can also cause lack of appetite and lead to underweight and malnutrition especially in the elderly who practice poly-pharmacy [98].

2.4.2. Overtraining & Exercise

Too much physical training and exercise without a corresponding consumption of nutritious food, coupled with not taking adequate rest, can lead to nutrient depletion, fatigue, loss of muscle mass and underweight, leading to syndromes like female athletic triad and RED-S [77], [78].

2.4.3. Underlying Illnesses and Disorders

Sometimes some underlying illnesses, especially organic diseases, lead to underweight even when a person eats ample amount of food [22], [98]. These underlying illnesses affecting different organ systems include:

- Endocrine disorders (diabetes type 1, newly diagnosed diabetes type 2, thyrotoxicosis),
- Gastrointestinal disorders, (dysphagia, mal-absorption

syndromes, lactose intolerances, nutrient allergy, irritable bowel diseases, pancreatitis, ulcers, gastro esophageal reflux disease or GERD),

-Respiratory disorders (tuberculosis, chronic obstructive pulmonary disease or COPD, emphysema, whooping cough),

-Musculo-skeletal disorders such as arthritis, immobility or reduced mobility, muscle wasting disease, muscle atrophy, polio,

-Neurological disorders (Alzheimer's disease, dementia, stroke, alcoholism, Parkinson's disease) etc

-Debilitating disorders affecting multiple body systems (cancers, Lou Gehrig's disease, multiple sclerosis, sickle cell diseases, TB, anemia),

-Various parasitic infections, for example, infections from helminthes (roundworms, hookworms, filarial worms), from insects (malaria parasites in mosquitoes), from bacteria (urinary tract infections or UTI, pneumonia, E.coli, Staph. aureus), from yeast & fungi (candidiasis, ringworm, aspergillosis), as well as viral infections (AIDS, Ebola, Zika, etc.).

2.4.4. Chronic and Wasting Diseases

Some people are chronically underweight because they have chronic diseases that cause weight loss and underweight. Others are underweight because they are living with wasting diseases that make them shrink in size once the diseases strike them. Such wasting diseases include tuberculosis or TB [114]-[116], multiple sclerosis or MS [113], cancer [129], pancreatitis [130], cystic fibrosis [131], HIV/AIDS [132], Lou Gehrig's disease [22] or people with idiopathic weight loss, as well as some viral diseases like Ebola viral disease [133], [134]. It should be noted that once a patient's tissue starts wasting, it is a sign of disease progression and a strong warning signal for clinicians [22] to do serious intervention on the patient.

2.4.5. Hyperactive Thyroid

Hyperactive thyroid leads to hyperthyroidism, a condition which produces high level of thyroid hormones namely, tri-iodo-thyronine (T3) and thyroxin (T4). The high level of thyroid hormones increases basal metabolic rate (BMR) and weight loss. People with high BMR hardly gain weight and tend to be underweight [110]-[112].

2.4.6. Lower and Upper GI Diseases

Diseases of upper and lower gastro intestinal tract that tend to negatively affect ingestion, digestion, absorption, metabolism and utilization of food lead to underweight, for example, irritable bowel disease (Cohn's and Celiac diseases) [40], [52], [103].

2.4.7. Genetics

Sometimes people are naturally underweight because of genetics, that is, they inherited 'lean genes' or 'skinny genes'. Such people do not gain weight even if they eat a lot of food because they have high basal metabolic rate (BMR) which was inherited. People with skinny genes tend to burn more body calories faster than their counterparts without

skinny genes [108], [109].

2.4.8. Food Avoidance and Eating Disorders

Deliberate starvation as occurs in people observing a hunger-strike can result in weight loss and underweight. Similarly, willful avoidance of food over a long period of time as done by some people during religious fasting can result in underweight. In addition, withholding food from a patient because of preparation for hospital procedures, before or after surgery, or in preparation for lab tests can negatively impact food intake and can result in underweight [22] if normal food consumption is not resumed soon afterwards.

Eating disorders especially in people living with anorexia nervosa & bulimia nervosa result in weight loss and underweight [36], [57], [93], [124], [125], [128].

2.4.9. Smoking

Smokers tend not to gain weight. This may be due to anorectic effects of nicotine, as reported in some studies [103,143]. Since nicotine in tobacco has anorectic effect, smokers therefore tend to be underweight [103], [143]. However sudden cessation of smoking tends to result in weight gain according to a published report [144].

2.4.10. Psycho-social, Economic and Political Causes

i. Food Insecurity

For many children and orphans in both developed and developing countries, the cause of underweight may include socio-economic as well as political causes. These include household food insecurity [27], [117]-[121], inadequate care of the children, war, famine, natural disasters, unhealthy household, poor health services and lack of access to good healthcare for mothers and children [72], [120].

ii. Unsafe and Unsanitary Drinking and Cooking Water

Underweight in children may also be caused by unsafe and unsanitary drinking and cooking water from toxic water supply. Unsafe water adversely affects the health and development of children in both developed and developing countries. Toxic chemicals in water supply include lead, arsenic, mercury, pesticides, herbicides and others. The recent lead crises due to toxic lead in the water supply in Flint Michigan USA negatively impacted the growth and health of many children in that community according to a recent report [126].

iii. Psycho-Social Causes of Underweight

Sometimes bereavement, trauma, fear, war, refugee status, sudden displacement, migration, and domestic violence can suppress appetite and lead to weight loss and underweight [106], [107].

iv. Excess Alcohol Intake in Lieu of Nutritious Food

Consuming excess alcohol while neglecting to eat balanced nutritious meals can cause underweight as essential

nutrients and calories necessary for the body and tissue building are not consumed [153].

v. Use of Hunger Suppressing Herbs

Certain herbs are reported to have hunger suppressing properties [154]. One such herb is known as 'khat' (*Catha edulis*), an evergreen shrub that grows in parts of the Middle East as well as the Sahel region of Africa (Yemen, Ethiopia, Somalia, and East Africa). Khat produces leaves that have narcotic and stimulant effects when the leaf is chewed or drunk as tea. The khat suppresses both appetite and hunger, so that people (especially men and nomadic herders) who consume this stimulant herb, look lanky or lean, and can go for several days or weeks in the field or desert without food. Such men do not feel hungry or tired, but they lose weight since their caloric intake is low. However chronic use of the herb has been reported to have serious adverse effects on the liver, nervous and cardiovascular system and the herb has been described as a drug of addiction [154], [155]. Khat chewers tend to be underweight and lanky. The herb is not allowed to be used by pregnant women and children because of its toxicological effects [155]-[157], though some women ignore medical advice and still take the stimulant herb. Khat is a controlled substance in many countries and banned in some others.

2.5. Management of Underweight

Based on the facts listed above, it is obvious that several causes of underweight exist and new causes are encountered in the field regularly. Although underweight is a public health problem especially in some developing countries, it has not reached epidemic proportions in developed countries like the USA, where underweight afflicts a small segment of their population, mainly some geriatric populations, some premature children, refugees and some children in very poor communities. Underweight problem can be more easily rectified with supervised nutritious diet, proper hydration, liquid supplements as well as vitamin and mineral supplements. In addition, underweight can be rectified by use of nutritious foods and beverages, and treating underlying disease conditions and symptoms, as well as supervised physical activity and medications. However rectifying overweight and obesity problems in developed countries require long term problem solving and interventions as shown by several government programs such as Healthy People Programs [158], [159]. These programs have addressed overweight and obesity issues for several years and there is still more work to be done.

2.6. Strategies to Rectify Underweight and Malnutrition

Several strategies have been found useful in rectifying underweight and malnutrition as listed in Table 3. These are discussed fully below.

2.6.1. Offer Foods of High Nutrient Density & High Energy Density in Small Amounts

To rectify underweight in affected people requires a balanced diet that is high in nutrients and energy. Underweight people should be given nutritious and well balanced food in small quantities, at a slow pace to avoid re-feeding syndrome, especially in patients living with anorexia [160]. This protocol is necessary to allow the body to adjust to presence of these nutrients, maintain electrolyte balance and to avoid overwhelming the undernourished body with excess nutrients that can affect the functions of vital body organs such as heart, kidney and the organs of the gastrointestinal system.

Soft drinks or sodas even though high in sugar tend to suppress appetite and prevent weight gain, therefore intake of these should be minimized to allow room for nutrient dense foods. In children, a moderate amount of 100% fruit juice taken after food is preferable to soft drinks; excess juice should however be disallowed to enable children have space in their GI tract to accommodate intake of macronutrients. In addition, ample amount of animal protein, plant proteins, healthy fats, and starchy vegetables as well as less fibrous foods, milk, other dairy and beverages should be given in small portions to ensure rebuilding of tissues. The menu should include items such as lean meat, oily fish, poultry and eggs, legumes (beans and peas), milk, avocado, various nuts and seeds. It should also include vegetable oils like olive oil which is high in mono-unsaturated fatty acids as well as more starchy vegetables like rice, pasta and potatoes, and less non-starchy vegetables. Non-starchy vegetables are high in fiber which easily fill up the consumer and prevent consumption of weight enhancing caloric macronutrients. The nutritionist should discuss food allergy and intolerances with the person living with underweight to ensure that all foods given to the person is allergen-free and well tolerated.

2.6.2. Offer Nutritional Supplements

Underweight people or malnourished patients are sometimes given oral nutritional supplements, energy dense formula, nutrient dense bars, multivitamin and minerals pills, fortified foods, medical foods, beverages, healthy snacks & shakes (such as Boost, Ensure, etc). In addition, full fat milk or full fat yogurt, high in calories and various nutrients, are also given.

2.6.3. Increase Food Frequency and Snacks

Increasing the frequency of food eaten is very helpful. Eating six small meals instead of two or three very big meals is also very helpful. Healthy snacks should be given after the main meals to help in weight gain and to fight the underweight problem.

2.6.4. Increase Organoleptic Properties of Food Served

Sensory appeal of food (good appearance, improved flavor-smell, aroma, & taste) as well as food texture (softness, hardness, mouth feel) improves consumption of

food for the child, adult or the elderly living with underweight [54].

2.6.5. Programmed Exercise

Training the underweight person in strength and flexibility exercises using weights such as dumb bells or resistance bands can build and tone muscle especially if done with several repetitions and under expert supervision [103]. Children and adolescents should be allowed to play regularly and get exposed to sunshine to absorb the sun's rays necessary to make vitamin D for absorbing calcium from food, for building strong bones and muscles as well as for bone growth [161]. Adults and the elderly should take gentle walks and get some sunshine regularly when possible and should also eat nutritious food to build bone and muscle [103].

2.6.6. Rest and Relaxation

In addition to exercise, people living with underweight issues need frequent rest and relaxation to regain or improve their energy levels [103].

2.6.7. Smoking Cessation

Smoking has anorectic effect on smokers, so anybody who wants to gain weight should stop smoking [143], [144].

2.6.8. Alcohol Cessation

Alcohol tends to fill the gut volume and make the consumer to eat less caloric food as there is no space to accommodate extra food if a person drank so much already. Eating caloric nutrients while avoiding or minimizing alcohol intake can improve appetite and weight gain and reduce underweight [162].

2.6.9. Use of Medications that Stimulate Appetite or Build Tissues

Appetite stimulators (e.g. megestrol, dronabinol) [163], or tissue building medications that boost anabolism (e.g. growth hormone, testosterone) are sometimes recommended and should be checked with the prescribing physician and licensed nutritionist before they are taken.

Conversely people using hunger suppressing herbs or appetite suppressing drugs should discontinue such products so as to stimulate appetite, increase food intake that will result in body weight gain.

Table 3. Strategies to Rectify Underweight and Malnutrition.

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| <ul style="list-style-type: none"> (i) Offer foods of high nutrient density and high energy density in small amounts. (ii) Offer nutritional supplements, beverages & shakes (iii) Increase food frequency and snacks. (iv) Increase organoleptic properties of food served. (v) Encourage programmed exercise, (vi) Encourage frequent rest and relaxation (vii) Encourage smoking cessation (vii) Encourage Alcohol cessation (viii) Offer medications that stimulate appetite or build tissues. (ix) Discontinue stimulant drugs or herbs that inhibit appetite or suppress hunger. |
|--|

2.7. Benefits of Adequate Caloric Intake from Food

Intake of adequate amount of calories from food is encouraged since the human body needs food calories to function properly. A problem only arises when there is excessive, uncontrolled or inadequate caloric consumption that negatively impacts health. There are several benefits of food calories when taken in moderation or to meet the body's energy needs. Food calories influence body weight, provide energy and macronutrients for body function and work. Food calories go hand in hand with various micro nutrients to fight malnutrition and underweight. Food calories ensure growth and they give strength and cultural pleasure.

2.7.1. Calorie Intake Influences Body Weight: Body Weight Impacts Health Status

Calories taken into the body through food can be metabolized to release energy or stored in the body as fat. When stored in the body, calories lead to weight gain and influence overall body weight. Body weight in the normal range is healthy and positively affects health status. Good nutrition which involves intake of healthy food calories is essential not only for growth and healthy development of a child, but also to fight infections and for repair and maintenance of tissues in both adult and children.

Healthy body weight is an essential metric used in many nutritional calculations to determine parameters for making important decisions in medical nutrition therapy (MNT) such as weight status and weight changes. Nutrient and energy needs as well as drug dosages are based on kilogram body weights. Similarly, tube feeding and intravenous feeds are also dependent on body weight status. The effects of adequate body weight on health status cannot be over-emphasized and these are discussed below.

i. Body Weight Determines Weight Status and Impacts Weight Changes

Calculation of nutrition parameters involves adequate body weight. Such parameters include BMI, ideal body weight (IBW), usual body weight (UBW) and actual or current body weight, which are used clinically to determine a person's weight status such as obesity, overweight, underweight or normal weight. Current body weight is also used to calculate percent changes in body weight such as %IBW, %UBW, usual body weight, calculated metabolic weight and adjusted weight for amputation. Body weight is also factored into the calculation of weight loss, involuntary weight loss, weight gain or weight regain.

ii. Body Weight Is Used to Determine Nutrient, Fluid, Energy Needs and Amount of Feeds

Body weight is taken into consideration when calculating energy, protein and fluid needs of hospitalized patients or patients on parenteral nutrition. Body weight is also used in calculation of amount of feed needed for tube

feeding and intravenous (i.v.) feeding of patients. Body weight is factored into the energy equations for determining daily energy or caloric requirements such as basal energy requirement and total energy expenditure. Such equations including Mifflin St Jeor Equation, Harris-Benedict equations and other energy equations for energy requirement estimation have been described in literature [164].

iii. Body Weight is Needed to Calculate Some Drug Dosages

Body weight is also used in calculation of dosage of drugs for patients; some drug dosages and feeds are based on units per kilogram body weight.

iv. Body Weight as an Indicator of Survivability

Body weight is an important indicator of nutritional or health status. Well nourished cancer or HIV/AIDS patients for example, with adequate body weight and good protein stores, have good survivability, while patients losing 10 or more percent of their body weight have diminished prognosis [22]. Similarly, children who have normal weight-for-age status or BMI-for-age percentile or children born with normal birth weight (≥ 2500 grams) are healthier, and more likely to fight infection and grow better than their counterparts with lower weight-for-age or lower BMI-for-age status. Infants born with normal birth weight or higher are also more likely to survive than those born with low birth weight or preterm.

2.7.2. Food Calories Prevent Malnutrition, Maintain Body Weight and Bone Mass

Good caloric intake helps to reduce risk of general malnutrition or protein energy malnutrition (formerly known as protein calorie malnutrition) in pre-school (<6years of age) children and older adults. Food calories are used in treating under-nutrition of macronutrients and deficiencies of vitamins and minerals; these micronutrients are also present in caloric foods. Food calories are also used to reverse both intentional and unintentional weight loss, to fight frailty and to maintain adequate body weight [50]. Food calories lead to weight gain which protects bones and prevents fractures [46]-[48].

2.7.3. The Food Calories Are Essential to Provide Energy

The energy from food calories is necessary to perform bodily metabolic activities and other physical and mental activities including sports and exercise as well as learning [66], [77]. Inadequate food calorie consumption leads to fatigue, weakness and lack of concentration [65].

2.7.4. Food Calories Support Growth, Build Blood and Tissues & Help Fight Infection

Food calories are also essential for growth of children and adolescents and for repair and maintenance of body tissues in adults and the elderly. Food calories fight diseases and infections, prevent anemia and help to build strong bones.

They help to heal wounds, prevent bedsores and to re-grow tissues that suffered burns or trauma. Food calories also help to build body tissues (bones, muscles and blood etc) and regulate chemical processes in the body [71].

2.7.5. Food Macronutrients Provide Calories and Essential Nutrients

Food macronutrients provide calories and essential nutrients including essential and non essential amino acids, essential fatty acids, vitamins and minerals necessary for the body to function well. Macronutrients build important biomolecules like hormones, antibodies, enzymes, transport proteins, growth factors, neuro-transmitters etc. The food calories along with other nutrients nourish the body properly and are needed by people suffering wasting diseases, as well as normal healthy people who need calories for body maintenance, tissue building and general body function.

2.7.6. Food Calories Give Cultural Pleasure

Caloric foods help many communities to perform social, physical, psychological and cultural functions in their neighborhoods and good food gives pleasure. These foods are used as celebratory foods or daily meals and they provide energy for both physical and mental work.

2.7.7. Food Calories Maintain Body Temperature

Calories from food increase body temperature. Body temperature maintenance is very important in cold regions of the world especially during the winter months [68].

3. Conclusion

Underweight is unhealthy weight arising from unintentional weight loss from many causes especially poor food intake. It is prevalent in children, pregnant and lactating women, adults and even the elderly in many countries especially developing countries. In developed countries, underweight is less talked about, less common, and under-recognized compared to obesity which is given more prominence. However in the USA, underweight is observed in some geriatric populations, a group where underweight can lead to malnutrition if there are barriers to appropriate nutritional care [165]. Underweight has various causes and adverse consequences that impact the health and quality of life of those affected.

Gradual diet restoration involving high caloric and nutritious food and beverages, fed in small portions, at a slow pace to avoid re-feeding syndrome, is the best approach to reverse underweight. Other strategies to reduce underweight and progress to healthy weight gain include gradual strength-training exercises that build muscle, frequent rest and good sleep, healthier life style and behavior modification. In addition, avoidance of smoking, alcohol, street drugs, hunger/appetite suppressants or quitting smoking and street drugs altogether, are helpful in weight regain. Offering nutritious foods to an underweight person, while concurrently treating underlying diseases and syndromes, removing

barriers to the access of healthy food and safe water, as well as good health policy initiatives help to treat underweight.

A joint action by public health and healthcare professionals, nutritionists, educators and policy makers is important to recognize, treat and prevent under-nutrition and underweight in many populations. Public health education on good nutrition and healthy weight maintenance will improve, maintain and promote overall good health and wellness in many countries.

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