Epidemiology of Adult and Pediatric Obesity

Frank Hu, MD, PhD
Professor and Chair
Dept. of Nutrition
Harvard School of Public Health
Professor of Medicine
Harvard Medical School
Outline

- Assessment of obesity: Anthropometry and imaging methods
- Adult and pediatric obesity time trends and epidemiologic characteristics
- Obesity-related health risks
- Genetic, environmental, and behavioral determinants of obesity
- Treatment options for obesity
Body mass index (person’s weight in kilograms divided by the square of height in meters)

• Uncorrelated with height
• Highly correlated with:
  • FM and % body fat
  • Adipocyte-secreted hormones
• Correlated with health risks
What is Obesity? (Adults)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Body Mass Index (BMI) (kg/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underweight</td>
<td>&lt; 18.5</td>
</tr>
<tr>
<td>Normal range</td>
<td>18.5 – 24.9</td>
</tr>
<tr>
<td>Overweight</td>
<td>25 – 29.9</td>
</tr>
<tr>
<td>Obese</td>
<td>≥ 30</td>
</tr>
<tr>
<td>Severe Obesity</td>
<td>≥ 40</td>
</tr>
</tbody>
</table>

World Health Organization 1995
### What is Obesity? (Children)

<table>
<thead>
<tr>
<th>Category</th>
<th>BMI-for-age percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underweight</td>
<td>&lt; 5&lt;sup&gt;th&lt;/sup&gt; percentile</td>
</tr>
<tr>
<td>Healthy weight</td>
<td>5&lt;sup&gt;th&lt;/sup&gt; - &lt;85&lt;sup&gt;th&lt;/sup&gt; percentile</td>
</tr>
<tr>
<td>Overweight *</td>
<td>≥ 85&lt;sup&gt;th&lt;/sup&gt; and &lt; 95&lt;sup&gt;th&lt;/sup&gt; percentile</td>
</tr>
<tr>
<td>Obesity *</td>
<td>≥ 95&lt;sup&gt;th&lt;/sup&gt; percentile</td>
</tr>
<tr>
<td>Severe Obesity</td>
<td>≥ 120% of 95&lt;sup&gt;th&lt;/sup&gt; percentile</td>
</tr>
</tbody>
</table>


Children's body composition varies as they age and varies between boys and girls. Therefore, BMI levels among children and teens are expressed relative to other children of the same age and sex - CDC.
Body mass index-for-age percentiles: Boys, 2 to 20 years

A 10-year-old boy with a BMI of 23 would be in the obese category (95th percentile or greater).

A 10-year-old boy with a BMI of 21 would be in the overweight category (85th to less than 95th percentile).

A 10-year-old boy with a BMI of 18 would be in the healthy weight category (5th percentile to less than 85th percentile).

A 10-year-old boy with a BMI of 13 would be in the underweight category (less than 5th percentile).
Abdominal obesity

- One limitation of BMI is that it does not assess fat distribution.
- Abdominal obesity is metabolically important.
- The simplest and most often used measure of abdominal obesity is waist size.
- Abdominal obesity is defined as a waist size of 35 inches or higher in women and a waist size of 40 inches or higher in men in the US.
APPLE SHAPED OBESITY

1. Excess amount of fat is accumulated above waist line i.e. in belly region
2. Associated with excess visceral and subcutaneous (somatic) fat
3. Abdominal girth is bigger than hip circumference
4. Most commonly associated with metabolic syndrome and related health problems

PEAR SHAPED OBESITY

1. Excess amount of fat is accumulated below waist line i.e. around hips and thighs
2. Waist is relatively thinner as compared to apple shaped obesity but has large hips
3. More commonly associated with subcutaneous fat
4. Associate less commonly with metabolic syndrome related health issues

www.healthonics.healthcare
DEXA (Dual-energy X-ray absorptiometry)

- Accurate estimates of FM, FFM and BMD
- Allows body composition analysis of specific body regions
- High correlations with reference methods (densitometry/CT)
- Minimal radiation: safe for children
- Does not accommodate severely obese
- Expensive, immobile equipment
Imaging (CT and MRI)

- Current “Gold Standard”: most accurate methods for total fat, fat distribution, and fat depot

- Cross-section of tissues allows:
  - Differentiation of subcutaneous and intra-abdominal fat
  - Estimation of fat content of solid organs (e.g. liver)
  - Direct measurement of muscle mass

- MRI suitable for children and pregnant women

- Expensive and not widely available, but optimal for validation of other methods
Bioelectric Impedance Analysis (BIA)

- FFM conducts electricity better than FM
- Estimate of total body fat using prediction equations
- Low cost, portable, simple to operate, low risk
- Overestimates %fat in lean; underestimates in obese
- Not superior to anthropometry predicting CVD risk factors
## Surveillance systems in the US

<table>
<thead>
<tr>
<th>NHANES</th>
<th>BRFSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐ Cross-sectional</td>
<td>☐ Cross-sectional</td>
</tr>
<tr>
<td>☐ Nationally representative</td>
<td>☐ State based (representative)</td>
</tr>
<tr>
<td>☐ In-person interview and physical exam</td>
<td>☐ Telephone survey of adults (cell phones since 2011)</td>
</tr>
<tr>
<td>☐ Continuous since 1999</td>
<td>☐ All states and D.C. participate since 1994</td>
</tr>
</tbody>
</table>
Trends in adult obesity NHANES

Age-adjusted trends in adult obesity

![Graph showing age-adjusted trends in adult obesity](image-url)
Obesity by sex and race/ethnicity

Hales et al. NCHS Data Brief No. 360. Feb 2020
Obesity by sex and education

Hales et al. JAMA 2018

FEMALES

MALES

Percent of the population

High school  Some college  College graduate
Obesity Trends* Among U.S. Adults

BRFSS, 2020

9 States > 35%
Lowest: CO, DC, MA
Highest: MS, WV, AL
Childhood obesity trends

Fryar et al. NCHS Health E-Stats 2020
Childhood obesity trends

Fryar et al. NCHS Health E-Stats 2020
Childhood obesity trends

Fryar et al. NCHS Health E-Stats 2020
Childhood obesity

Ogden et al. JAMA 2018

<table>
<thead>
<tr>
<th>Gender</th>
<th>Non-Hispanic White</th>
<th>Non-Hispanic Black</th>
<th>Non-Hispanic Asian</th>
<th>Hispanic</th>
</tr>
</thead>
<tbody>
<tr>
<td>GIRLS</td>
<td>14.1</td>
<td>23</td>
<td>7.4</td>
<td>20.6</td>
</tr>
<tr>
<td>BOYS</td>
<td>15.3</td>
<td>17.9</td>
<td>11.9</td>
<td>24.3</td>
</tr>
</tbody>
</table>
Childhood obesity by education of household head

Ogden et al. JAMA 2018

Head of household education

- High School
- Some College
- College
Racial/ethnic differences in body composition

- Asians, especially South Asians, are more likely to have less muscle and more abdominal fat than whites with the same BMI.
- Asians tend to develop diabetes and other metabolic disease at lower BMI levels.
- Lower BMI cutoff points are used to define overweight and obesity in Asian populations.
• Worldwide obesity has nearly tripled since 1975.
• In 2016, more than 1.9 billion adults, were overweight or obese (650 million were obese).
• In 2016, 39% of adults were overweight or obese (13% were obese).

http://www.who.int/mediacentre/factsheets/fs311/en/
Adipose Tissue as an Endocrine Organ

↑ IL-6
↓ Adiponectin
↑ Leptin
↑ TNFα
↑ Adipsin (Complement D)
↑ Plasminogen activator inhibitor-1 (PAI-1)
↑ Lipoprotein lipase
↑ Angiotensinogen
↑ Insulin
↑ FFA
↑ Resistin
↑ Leptin
↑ Lactate
↓ Adiponectin

Inflammation
Hypertension
Atherogenic dyslipidemia
Type 2 diabetes
Thrombosis

Medical complications of obesity

Pulmonary disease
- abnormal function
- obstructive sleep apnea
- hypoventilation syndrome

Nonalcoholic fatty liver disease
- steatosis
- steatohepatitis
- cirrhosis

Gall bladder disease

Gynecologic abnormalities
- abnormal menses
- infertility
- polycystic ovarian syndrome

Osteoarthritis

Skin

Gout

Idiopathic intracranial hypertension

Stroke

Cataracts

Coronary heart disease
- Diabetes
- Dyslipidemia
- Hypertension

Cancer
- breast, uterus, cervix
- colon, esophagus, pancreas
- kidney, prostate

Phlebitis
- venous stasis
Cancers Associated with Overweight and Obesity Make up 40 percent of Cancers Diagnosed in the United States

13 cancers are associated with overweight and obesity

https://www.cdc.gov/vitalsigns/obesity-cancer
Factors responsible for disease severity and poor outcome in obese COVID-19 patients. Obesity-associate chronic inflammation, impaired Immune function and increased ACE2 expression results in an increased disease severity and worse clinical outcome in obese subjects with COVID-19 infection (Immunity & Ageing volume 18, 2021)
HRs for all-cause mortality by pre-defined categories of BMI

Lancet 2016

Global BMI-mortality consortium
Obesity is heritable

- Family studies, twin studies, and adoption studies have provided evidence about heritability of obesity
- The mean correlations for BMI were 0.74 for monozygotic (MZ) twins, 0.32 for dizygotic (DZ) twins, and 0.25 for siblings.
Monogenic obesity

• Rare forms of obesity caused by mutations in a single gene
• Such mutations have been discovered in genes that play essential roles in appetite control, food intake, and energy homeostasis
• Primarily, in genes that code for the hormone leptin, the leptin receptor, pro-opiomelanocortin (POMC), and the melanocortin-4 receptor (MC4R).
Response to leptin therapy in congenital leptin deficiency

- Leptin, a hormone produced by adipose tissue, plays a key role in regulating food intake and energy homeostasis.
- *Ob/ob* mice with a homozygous *Lep* gene mutation exhibit leptin deficiency and early-onset morbid obesity and diabetes.

Leptin resistance in obesity

- In obese humans, leptin is elevated but lacks expected effect in suppressing appetite and controlling food intake
- Analogous to insulin resistance in type 2 diabetes
- Treatment with leptin alone is ineffective in decreasing food intake and body weight in obese humans
Ghrelin (hunger hormone)

- Ghrelin is a peptide hormone produced by stomach cells.
- Ghrelin increases before a meal and decreases after a meal.
- Ghrelin levels increase after diet-induced weight loss (body weight defense mechanism).
- Ghrelin levels decrease after gastric bypass surgery.

Cummings et al., NEJM, 2002
Genetics of common forms of obesity

- Using genome-wide association studies (GWAS), >500 BMI-associated genetic variants have been identified.
- The effect sizes of individual SNPs are modest.
- These variants are not predictive of future risk of obesity.
- Many of identified genes are expressed in hypothalamus and involved in appetite control and energy metabolism.

Gene-environment interactions

• Nature (biological, genetic factors) vs. nurture (behavioral, environmental)

• Monogenic obesity is almost 100% genetic, but common forms of obesity result from interplays between genes and environment

• G X E interaction studies examine how genetic predisposition to obesity modifies the effect of the environment and how changes in diet and lifestyle influence genetic risk of obesity

Obesogenic food environment

- Widely accessible cheap highly processed foods
- Sugar, especially beverages
- Unhealthy fats (saturated and trans fats), sodium
- Availability of convenient and fast foods
- Few vegetables, fruits, whole grains, legumes, fiber

http://www.foodispower.org/fast-food/
Gut microbiota and obesity

- The human gut contains about 100 trillion microorganisms, whose collective genome, the microbiome, contains 100-fold more genes than the entire human genome.

- Obesity-promoting bacteria can increase dietary energy harvest, promote fat deposition, and trigger systemic inflammation.

- Modulation of the gut microbiome through diet, pre- and probiotics, bariatric surgery, and fecal transplantation has the potential to prevent and treat obesity.

Gut microbiota transplant and obesity

- Transferring gut microbiota from lean or obese human twins produces the same phenotypes in mice.
- Safety and long-term efficacy of fecal transplantation in obesity prevention and treatment in humans are uncertain.

Ridaura et al. Science 2013
Walker AW and Parkhill, J. Science 2013
Secondary Causes of Obesity

- Hypothyroidism
- Cushing’s syndrome
- Insulinoma
- Hypothalamic obesity
- Polycystic ovarian syndrome
- Genetic syndromes (Prader Willi, Alstroms, Bardet Biedl, Cohens, Borjeson Forsmsman Lehmann and Frohlich’s syndrome)
- Growth hormone deficiency
- Oral contraceptive use
- Pregnancy
- Medication related
- Smoking cessation
- Eating disorders (binge eating disorder, bulimia nervosa and night eating disorder)
- Hypogonadism
- Pseudohypoparathyroidism
- Tube feeding related obesity

https://emedicine.medscape.com/article/123702-clinical
COMMON TREATMENTS FOR OBESITY

LIFESTYLE CHANGES
This typically includes weight-loss efforts designed to help people consume fewer calories and increase physical activity, sometimes directed by your doc.

PHARMACOTHERAPY
When your BMI is 27 or more, you may qualify for an appetite-suppressing medication that can help you with your prescribed nutrition and exercise program.

PRESCRIBED NUTRITION
This is a step beyond lifestyle changes and entails a doctor-directed diet tailored to your body, including vegan eating, intermittent fasting, and others.

SURGERY
Bariatric surgery is the most effective treatment for obesity, but it also carries the most risk. It’s typically used in those whose BMI is 40 or higher.

https://www.healthcentral.com/condition/obesity
Summary

• The prevalence of obesity especially severe obesity has increased dramatically in the past several decades (10% US adults and 6% children have severe obesity).

• Obesity rates vary substantially across different racial, education, and SES groups as well as geographic locations.

• Adipose tissue is considered the largest endocrine organ secreting hormones and cytokines that increase risk of chronic diseases.

• The pathophysiology of obesity is complex involving a multitude of genetic, environmental, hormonal, and psychosocial factors. Increasing evidence indicates an important role of gut microbiome in obesity.

• More effective treatment options such as medications and metabolic surgeries have become available, but obesity prevention remains a top public health priority.