BODY COMPOSITION IN HEALTHY PEOPLE

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Body composition in healthy subjects

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Equiliberty Consulting, LLC
Body composition levels

Body composition on the atomic level (I) for the 70-kg Reference Man

<table>
<thead>
<tr>
<th>Element</th>
<th>Amount (kg)</th>
<th>% Body Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen</td>
<td>43.0</td>
<td>61.0</td>
</tr>
<tr>
<td>Carbon</td>
<td>16.0</td>
<td>23.0</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>7.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>1.8</td>
<td>2.6</td>
</tr>
<tr>
<td>Calcium</td>
<td>1.0</td>
<td>1.4</td>
</tr>
<tr>
<td>Remainder</td>
<td>1.2</td>
<td>2.0</td>
</tr>
</tbody>
</table>

Human body: ~ 50 elements

- 98% (5 elements)
- 2% (45 elements)

P, S, K, Na, Cl, Mg…

### Food composition on the atomic level

#### Elements in the Six Classes of Nutrients

The nutrients that contain carbon are organic.

<table>
<thead>
<tr>
<th></th>
<th>Carbon</th>
<th>Oxygen</th>
<th>Hydrogen</th>
<th>Nitrogen</th>
<th>Minerals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>Carbohydrate</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>Fat</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>Protein</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Vitamins</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Minerals</td>
<td></td>
<td></td>
<td></td>
<td>✔</td>
<td>✔</td>
</tr>
</tbody>
</table>

*a* All of the B vitamins contain nitrogen; *amine* means nitrogen.

*b* Protein and some vitamins contain the mineral sulfur; vitamin $B_{12}$ contains the mineral cobalt.
Body composition levels

Body composition on molecular level (II) for the 70 kg man

- **Protein**: 15% (10.6 kg)
- **Carbohydrate**: 0.5% (400 g)
- **Lipid**: 19% (13 kg)
- **Mineral compounds**: 5.3 (3.7 kg)
- **Water**: 60% (42 kg)

- **Lipid ≠ Fat**
- **Triglycerides = Fatty acids + glycerol**
- **Lipids = Fat + 10%**

Body composition levels

Fat mass

Fat-free body mass

Non-essential fat

Essential fat

Lean mass

Body composition levels

Body composition on cellular level (III)

ECF = plasma + interstitial fluid

Body cell mass:
- muscle cells
- connective cells
- epithelial cells
- nervous cells

Body cell mass:
- protoplasm in fat cells
≠ stored fat cells (~85% of fat cell weight)

Body composition levels

Body composition on tissue level (IV) for the 70 kg Reference Man

- Liver, kidney, heart, brain = 5%
- Residuals (skin, lung, gastrointestinal tract...) = 15%

Global trends in healthy life expectancy and early death and disability

Highlights

- Globally, in 2017, life expectancy was 73 years, but healthy life expectancy was only 63 years. This means on average 10 years of life were spent in poor health in 2017.
- Trends in early death and disability, 1990-2017:
  - 41% decrease in communicable diseases and neonatal disorders
  - 40% increase in non-communicable diseases
  - Large disparities persist in health and disease burden by sex and level of development

What's new in this study

“Global, regional, and national disability-adjusted life-years (DALYs) for 359 diseases and injuries and healthy life expectancy (HALE) for 195 countries and territories, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017” is based on more data than ever before. Nineteen new causes were added for a total of 359 causes. The study also includes a more detailed analysis of healthy life expectancy.

*Early death and disability is measured in terms of number of all-ages disability-adjusted life-years (DALYs).
<table>
<thead>
<tr>
<th>Morbidity and Risk Factors</th>
<th>Fair or poor health, percent</th>
<th>Heart disease (ever told), percent</th>
<th>Cancer (ever told), percent</th>
<th>Diabetes,(^3) percent</th>
<th>Hypertension,(^2) percent</th>
<th>Hypercholesterolemia,(^4) percent</th>
<th>Obesity, percent</th>
<th>Cigarette smoking, percent</th>
<th>Aerobic activity and muscle strengthening,(^6) met both guidelines, percent</th>
</tr>
</thead>
</table>
Age standardized prevalence of overweight (BMI≥25 kg/m²) and obesity (BMI≥30 kg/m²) in adults >20 years old by geographical region and year.

BMI = body mass index

Chooi Y.C The epidemiology of obesity. Metabolism 2019; 92: 6-10
Body mass index and all cause mortality

Prospective Studies Collaboration

57 prospective studies
66,552 subjects

Figure 6: All-cause mortality at ages 35–79 years versus BMI in the range 15–50 kg/m², by smoking status (excluding the first 5 years of follow-up)
<table>
<thead>
<tr>
<th>BMI</th>
<th>kg/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underweight</td>
<td>&lt;18.5</td>
</tr>
<tr>
<td>Normal</td>
<td>18.5–24.9</td>
</tr>
<tr>
<td>Overweight</td>
<td>25.0–29.9</td>
</tr>
<tr>
<td>Obesity, class</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>30.0–34.9</td>
</tr>
<tr>
<td>II</td>
<td>35.0–39.9</td>
</tr>
<tr>
<td>III</td>
<td>≥40</td>
</tr>
</tbody>
</table>
BMI method as a measure of obesity

- Gender, age, and ethnic group are important variables.
Prevalence of BMI categories and metabolic status, by race/ethnicity.

Top. Prevalence of BMI category, by race/ethnicity. Error bars are 95% CIs. Bottom. Prevalence of metabolic abnormality, by BMI category and race/ethnicity. Metabolically abnormal was defined as the presence of ≥2 of the following components: decreased high density lipoprotein cholesterol levels (<1.036 mmol/L [<40 mg/dL] in men or <1.295 mmol/L [<50 mg/dL] in women or use of lipid-lowering medication), elevated triglyceride levels (fasting triglyceride levels ≥1.7 mmol/L [≥150 mg/dL]), elevated glucose levels (fasting plasma glucose level ≥5.6 mmol/L [≥100 mg/dL] or use of glucose-lowering medication), and high blood pressure (≥130/85 mm Hg or use of antihypertensive medication). Error bars are 95% CIs. BMI = body mass index.
Race/ethnicity-specific BMI values associated with MAN compared with whites with a BMI of 25 kg/m².

Gujral UP et al. 2017;166:628-636
BMI method as a measure of obesity

- Gender, age, and ethnic group are important variables.

- BMI has good specificity, but poor sensitivity.
Accuracy of body mass index in diagnosing obesity in the adult general population

A Romero-Corral¹, VK Somers¹, J Sierra-Johnson¹², RJ Thomas¹, ML Collazo-Clavell³, J Korinek¹, TG Allison¹, JA Batsis⁴, FH Sert-Kuniyoshi¹ and F Lopez-Jimenez¹

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Background: Body mass index (BMI) is the most widely used measure to diagnose obesity. However, the accuracy of BMI in detecting excess body adiposity in the adult general population is largely unknown.

Methods: A cross-sectional design of 13,601 subjects (age 20–79.9 years; 49% men) from the Third National Health and Nutrition Examination Survey. Bioelectrical impedance analysis was used to estimate body fat percent (BF%). We assessed the diagnostic performance of BMI using the World Health Organization reference standard for obesity of BF% > 25% in men and > 35% in women. We tested the correlation between BMI and both BF% and lean mass by sex and age groups adjusted for race.

Results: BMI-defined obesity (≥ 30 kg m⁻²) was present in 19.1% of men and 24.7% of women, while BF%-defined obesity was present in 43.9% of men and 52.3% of women. A BMI ≥ 30 had a high specificity (men = 95%, 95% confidence interval (CI), 94–96 and women = 99%, 95% CI, 98–100), but a poor sensitivity (men = 36%, 95% CI, 35–37 and women = 49%, 95% CI, 48–50) to detect BF%-defined obesity. The diagnostic performance of BMI diminished as age increased. In men, BMI had a better correlation with lean mass than with BF%, while in women BMI correlated better with BF% than with lean mass. However, in the intermediate range of BMI (25–29.9 kg m⁻²), BMI failed to discriminate between BF% and lean mass in both sexes.

Conclusions: The accuracy of BMI in diagnosing obesity is limited, particularly for individuals in the intermediate BMI ranges, in men and in the elderly. A BMI cutoff of ≥ 30 kg m⁻² has good specificity but misses more than half of people with excess fat. These results may help to explain the unexpected better survival in overweight/mild obese patients.

Diagnostic performance of body mass index to identify obesity as defined by body adiposity: a systematic review and meta-analysis

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¹University of Missouri School of Medicine, Columbia, MO, USA; ²Division of Cardiovascular Diseases, Department of Internal Medicine, Mayo Clinic College of Medicine, Mayo Foundation, Rochester, MN, USA; ³Division of Endocrinology, Department of Internal Medicine, Mayo Clinic College of Medicine, Mayo Foundation, Rochester, MN, USA and ⁴Mayo Clinic Libraries, Mayo Clinic College of Medicine, Mayo Foundation, Rochester, MN, USA

Objective: We performed a systematic review and meta-analysis of studies that assessed the performance of body mass index (BMI) to detect body adiposity.

Design: Data sources were MEDLINE, EMBASE, Cochrane, Database of Systematic Reviews, Cochrane CENTRAL, Web of Science, and SCOPUS. To be included, studies must have assessed the performance of BMI to measure body adiposity, provided standard values of diagnostic performance, and used a body composition technique as the reference standard for body fat percent (BF%) measurement. We obtained pooled summary statistics for sensitivity, specificity, positive and negative likelihood ratios (LRs), and diagnostic odds ratio (DOR). The inconsistency statistic (I²) assessed potential heterogeneity.

Results: The search strategy yielded 3341 potentially relevant abstracts, and 25 articles met our predefined inclusion criteria. These studies evaluated 32 different samples totaling 31,968 patients. Commonly used BMI cutoffs to diagnose obesity showed a pooled sensitivity to detect high adiposity of 0.50 (95% confidence interval (CI): 0.43–0.57) and a pooled specificity of 0.90 (CI: 0.86–0.94). Positive LR was 5.88 (CI: 4.24–8.15), I² = 97.8%; the negative LR was 0.43 (CI: 0.37–0.50), I² = 98.5%; and the DOR was 17.91 (CI: 12.56–25.53), I² = 91.7%. Analysis of studies that used BMI cutoffs ≥ 30 had a pooled sensitivity of 0.42 (CI: 0.31–0.43) and a pooled specificity of 0.97 (CI: 0.96–0.97). Cutoff values and regional origin of the studies can only partially explain the heterogeneity seen in pooled DOR estimates.

Conclusion: Commonly used BMI cutoff values to diagnose obesity have high specificity, but low sensitivity to identify adiposity, as they fail to identify half of the people with excess BF%.

International Journal of Obesity (2010) 34, 791–799; doi:10.1038/ijo.2010.5; published online 2 February 2010
BMI-defined normal weight subjects and mortality

N = 977 normal weight subjects (BMI=18.5-24.9 kg/m²)

Metabolic abnormalities considered:

1. Elevated blood pressure\(^b\): \(\geq 130/85\) mm Hg
2. Elevated TG\(^b\): \(\geq 1.70\) mmol/L
3. Decreased HDL-C\(^b\): Men < 1.04 mmol/L
   \hspace{1cm} Women < 1.30 mmol/L
4. Elevated glucose\(^b\): \(\geq 5.6\) mmol/L
5. Insulin Resistance: HOMA-IR > 2.52 (ie. 90th percentile)
6. Inflammation: hsCRP level > 5.07 mg/L (ie. 90th percentile)

\(^a\) Subjects having \(\geq 2\) characteristics were classified as being metabolically abnormal. Subjects with \(\leq 1\) characteristic were considered metabolically healthy. TG, triacylglycerol; HDL-C, HDL cholesterol; HOMA-IR, homeostasis model for insulin resistance; hsCRP, high-sensitivity C-reactive protein.

\(^b\) Or on medication for any of these conditions.
BMI method as a measure of obesity

- Gender, age, and ethnic group are important variables.
- BMI has good specificity, but poor sensitivity, with approximately half of individuals who have excessive BF% being labeled as non-obese.
- The odds of being metabolically abnormal nearly tripled for the highest %BF tertile group among BMI-defined normal weight subject.
- BMI is it does not capture BF location information, with visceral and android fat being strongly correlated with most metabolic risk factors.

\[ %BF = \text{percent body fat} \]
BMI method as a measure of obesity

- The correlation of mortality rates with BMI is influenced by numerous factors that are often not taken into consideration.

- BMI is a poor predictor in total fat mass changes.

- No correlation of mortality rates with BMI should be made if the fitness level of the subjects are taken into consideration.
Long term effects of changes in cardiovascular fitness & BMI

14,345 men
Fitness = maximal treadmill test

Hazard ratios (95% confidence intervals) of all-cause (A) and cardiovascular disease (CVD) (B) mortality by combinations of changes in fitness and BMI in 14,345 men. All data were adjusted for age, examination year, parental CVD, BMI, and maximal METs at baseline, the combination patterns of each lifestyle factor (smoking status, alcohol intake, and physical activity) and each medical condition (abnormal ECG, hypertension, diabetes, and hypercholesterolemia) at the baseline and last examinations, and the number of clinic visits between the baseline and last examinations.

Relative mortality risk according to body mass index (BMI) and fitness categories.
<table>
<thead>
<tr>
<th>Health Outcome</th>
<th>PA Type</th>
<th>Minimum Amount</th>
<th>Intensity</th>
<th>% Risk Reduction</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>All-Cause Mortality</td>
<td>Aerobic</td>
<td>5 30</td>
<td>moderate 3-5.9 METs</td>
<td>30% ↓</td>
<td>All-Cause Mortality</td>
</tr>
<tr>
<td>Cardiorespiratory</td>
<td>Aerobic</td>
<td>5 30</td>
<td>vigorous &gt; 6 METs</td>
<td>20-35% ↓</td>
<td>Coronary Heart Disease Cardiovascular Disease Stroke</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.5%-20% ↑</td>
</tr>
<tr>
<td>Cancer</td>
<td>Aerobic</td>
<td>7 30-60</td>
<td>moderate 3-5.9 METs</td>
<td>30% ↓</td>
<td>Colon &amp; Endometrial Cancer</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>vigorous &gt; 6 METs</td>
<td>20% ↓</td>
<td>Breast Cancer</td>
</tr>
<tr>
<td>Metabolic</td>
<td>Aerobic</td>
<td>5 30</td>
<td>vigorous &gt; 6 METs</td>
<td>30-40% ↓</td>
<td>Type 2 Diabetes Metabolic Syndrome</td>
</tr>
<tr>
<td>Energy Balance</td>
<td>Weight Stability (1-3%)</td>
<td>Aerobic; Resistance</td>
<td>5 30</td>
<td>1-3% ↓</td>
<td>Weight</td>
</tr>
<tr>
<td></td>
<td>Weight Loss (≥5%)</td>
<td>Aerobic</td>
<td>7 70</td>
<td>≥5% ↓</td>
<td>Weight</td>
</tr>
<tr>
<td></td>
<td>Weight Stability following Weight Loss</td>
<td>Aerobic</td>
<td>7 50-80</td>
<td>Weight Stability</td>
<td></td>
</tr>
<tr>
<td>Musculo-skeletal</td>
<td>Bone</td>
<td>Weight bearing, endurance 3-5 30-60</td>
<td></td>
<td>36-68% ↓</td>
<td>Hip Fracture</td>
</tr>
<tr>
<td></td>
<td>Joint</td>
<td>Aerobic; Resistance</td>
<td>3-5 30-60</td>
<td>1-2% ↑</td>
<td>Bone Mineral Density</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>22-83% ↓</td>
<td>Osteoarthritis</td>
</tr>
<tr>
<td>Functional</td>
<td>Aerobic</td>
<td>3-5 30-90</td>
<td>vigorous &gt; 6 METs</td>
<td>30% ↓</td>
<td>Delay in Function</td>
</tr>
<tr>
<td>Prevention of Falls</td>
<td>Aerobic</td>
<td>2 30</td>
<td>vigorous &gt; 6 METs</td>
<td>30% ↓</td>
<td>Risk of Falls</td>
</tr>
<tr>
<td></td>
<td>Resistance, Balance</td>
<td>3 30</td>
<td></td>
<td></td>
<td>Depression Distress/Well-Being Dementia</td>
</tr>
<tr>
<td>Mental</td>
<td>Aerobic; Resistance</td>
<td>3-5 30-60</td>
<td>vigorous &gt; 6 METs</td>
<td>20-30% ↓</td>
<td>Depression Distress/Well-Being Dementia</td>
</tr>
</tbody>
</table>
Conclusion

mortality risk was not increased for high-fit individuals across BMI categories
BMI method as a measure of obesity

- BMI is rather poor indicator of percent of body fat.
- BMI has good specificity, but poor sensitivity, with half of subjects who have excessive BF% being labeled as non-obese.
- BMI fails to consider the all-important component of body fat distribution, and is a poor predictor in total fat mass changes over time.
- Mortality risk are not increased for high-fit individuals across BMI categories.
- No correlation of mortality rates with BMI should be made if the fitness level of the subjects are taken into consideration.
Thank you