Body Mass Index vs. Other Body Composition Methods To Identify Children At Risk Of Cardiometabolic Complications Of Obesity

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Complications Of Childhood Obesity

Psychosocial
- Poor self esteem
- Depression
- Eating Disorders

Neurological
- Pseudotumor cerebri

Pulmonary
- Sleep apnea
- Asthma
- Exercise intolerance

Cardiovascular
- Dyslipidemia
- Hypertension
- Chronic inflammation
- Endothelial dysfunction

Gastrointestinal
- Gallstones
- Steatohepatitis

Endocrine
- Type 2 diabetes
- Precocious puberty
- Polycystic ovary syndrome (girls)
- Hypogonadism (boys)

Renal
- Glomerulosclerosis

Musculoskeletal
- Slipped capital femoral epiphyses
- Blount's disease
- Forearm fracture
- Flat feet

Prevalence Of Dyslipidemia And Borderline High Or High BP In Children 2011-2012 (NHANES)

Adapted from Kit et al. JAMA Pediatrics 2015
What is the best way to identify excess adiposity?

What is the best way to identify those at greatest risk of health complications of obesity?

Assessing Excess Adiposity

- BMI is most widely used screening tool
  - Height and weight measures are relatively easy to obtain
  - Requires minimal skill, equipment, space to acquire measurements
  - Excellent reference data to define overweight and obesity
  - Useful at all levels (population, clinic, research, etc)
Assessing Excess Adiposity

- Limitations of BMI
  - Doesn’t distinguish between fat and lean mass
High BMI Is A Good Indicator Of Excess Adiposity

Fat mass index and fat free mass index according to BMI-for-age z score in the Pediatric Rosetta Study (n=1186)

Solid lines represent boys, and the dashed lines represent girls

From Freedman and Sherry
Assessing Excess Adiposity

- Limitations of BMI
  - Doesn’t distinguish between fat and lean mass
  - BMI correlates well with lean mass
  - BMI correlates well with fat mass at the upper end of the BMI distribution
  - Relationship of BMI to fat mass varies by age and sex
  - Doesn’t measure fat distribution – “harmful fat”
Not All Fat Is Created Equal
Visceral vs Subcutaneous Fat

- 28 healthy weight and 44 obese adolescents
- Visceral adipose tissue volume increases exponentially as BMI increases
Fat partitioning patterns [transverse magnetic resonance imaging (MRI) slices (L2–L3)] in obese Caucasian (A) and African-American (B) females. Demographics: (A) 14.3-yr old, Tanner 4, body mass index (BMI) 34.7, and BMI Z-score 2.29. (B) 14.8-yr old, Tanner 4, BMI 37.2, and BMI Z-score 2.43. From Koren et al. *Pediatric Diabetes* 2013: 14: 575–584.
Waist Circumference And Visceral Fat

Waist circumference correlates well with cross-sectional measures of total fat, subcutaneous fat and visceral fat in 145 children, ages 8 to 17y


Waist circumference correlates well with all fat depots


Waist circumference correlates well with all fat depots
Waist Circumference

- Surrogate marker of visceral adiposity
- Doesn’t distinguish between subcutaneous and intra-abdominal fat depots
- Measurement issues
  - Modesty
  - Different measurement protocols
Waist Circumference Measurement Sites

- NHANES: top of the iliac crest
  - Requires palpation
  - Landmark can be difficult to find in obese children
  - Not a natural minimum, so tape measure can be difficult to place on the body contour

NHANES Anthropometry Procedures Manual Jan 2011, p 3-20
Waist Circumference Measurement Sites

- NHANES: top of the iliac crest
- WHO: midpoint between the last palpable rib and top of the iliac crest
  - Requires palpation
  - Difficult landmarks to identify in obese children

http://www.statcan.gc.ca/pub/82-003-x/2012003/article/11707/c-g/fig1-eng.gif

https://www.phenxtoolkit.org/toolkit_content/web/anthropometrics/Waist_Circumference_Exhibit1_1.jpg
Waist Circumference Measurement Sites

- NHANES: top of the iliac crest
- WHO: midpoint between the last palpable rib and top of the iliac crest
  - Requires palpation
  - Difficult landmarks to identify in obese children
- Natural waist (minimum)
- NIH Multi-Ethnic Study of Atherosclerosis (MESA) study: level of the umbilicus or navel

https://www.phenxtoolkit.org/toolkit_content/web/anthropometrics/Waist_Circumference_Exhibit1_1.jpg
Which Is The Best Waist Circumference Measurement Site?

Johnson et al. 2010 compared waist circ. site to MetS and risk factors

- fasting insulin, glucose, cholesterol level, BP
- 73 overweight and obese children, 8 to 17 years of age
- Narrow waist and mid-point had greatest odds ratio for metabolic syndrome and risk factors

Johnson et al. J Peds 156(2): 247-252, 2010. Association of waist circumference and BMI z-score with (A) Metabolic Syndrome; and (B) # of risk factors. *P < .05
### Waist Circumference vs. BMI In Predicting Insulin Resistance

<table>
<thead>
<tr>
<th>Model number</th>
<th>Independent Variable</th>
<th>Beta</th>
<th>SE</th>
<th>p</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Age</td>
<td>-0.023</td>
<td>0.018</td>
<td>0.207</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sex</td>
<td>-0.024</td>
<td>0.051</td>
<td>0.640</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Race</td>
<td>0.118</td>
<td>0.051</td>
<td>0.022</td>
<td></td>
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<tr>
<td></td>
<td>Pubertal Status</td>
<td>-0.258</td>
<td>0.085</td>
<td>0.003</td>
<td>0.22</td>
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<tr>
<td>2</td>
<td>BMI percentile</td>
<td>-0.251</td>
<td>0.065</td>
<td>&lt;.001</td>
<td>0.30</td>
</tr>
<tr>
<td>3</td>
<td>BMI percentile</td>
<td>0.118</td>
<td>0.067</td>
<td>0.080</td>
<td></td>
</tr>
<tr>
<td></td>
<td>and WC</td>
<td>-2.772</td>
<td>0.320</td>
<td>&lt;.001</td>
<td>0.56</td>
</tr>
</tbody>
</table>

145 normal and obese children, ages 8 to 17y (Lee et al. J Pediatr 2006;148:188-94)
## Waist Circumference vs. BMI In Predicting Insulin Resistance

| Model number | Independent Variable | Beta   | SE    | p     | R²  | Model number | Independent Variable | Beta   | SE    | p     | R²  |
|--------------|----------------------|--------|-------|-------|-----|--------------|----------------------|--------|-------|-------|-----|-----|
| 1            | Age                  | -0.023 | 0.018 | 0.207 | 1   | Age          | -0.023 | 0.018 | 0.207 | 1   |     |
|              | Sex                  | -0.024 | 0.051 | 0.640 | 1   | Sex          | -0.024 | 0.051 | 0.640 | 1   |     |
|              | Race                 | 0.118  | 0.051 | 0.022 | 1   | Race         | 0.118  | 0.051 | 0.022 | 1   |     |
|              | Pubertal Status      | -0.258 | 0.085 | 0.003 | 0.22| Pubertal status | -0.258 | 0.085 | 0.003 | 0.22|     |
| 2            | BMI percentile       | -0.251 | 0.065 | <.001 | 0.30| WC           | -2.413 | 0.249 | <.001 | 0.55|     |
|              | and WC               | -2.772 | 0.320 | <.001 | 0.56| BMI Percentile | 0.118  | 0.067 | 0.080 | 0.56|     |

145 normal and obese children, ages 8 to 17y (Lee et al. J Pediatr 2006;148:188-94)
Waist To Height Ratio

- Shown to be a good predictor of cardiometabolic risk in adults
- Mokha et al. BMC Pediatrics 2010, 10:73
- Bogalusa Heart Study: 2,581 healthy weight children, 510 obese children
- Does a high waist to height ratio identify children with elevated CMR among those who have a health weight?
- Does a low waist to height ratio identify children with lower CMR among those who are obese?
Waist To Height Ratio

Table 2 Odds Ratios and 95% CI for adverse levels of cardiometabolic risk factor variables in normal weight and overweight/obese children: The Bogalusa Heart Study

<table>
<thead>
<tr>
<th>Independent Variable (Top tertile vs. rest)*</th>
<th>OR</th>
<th>95% CI</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Arterial Pressure (mm Hg)</td>
<td>1.30</td>
<td>0.92-1.83</td>
<td>0.13</td>
</tr>
<tr>
<td>LDL Cholesterol (mg/dl)</td>
<td>1.66</td>
<td>1.18-2.32</td>
<td>0.003</td>
</tr>
<tr>
<td>Triglycerides (mg/dl)</td>
<td>1.47</td>
<td>1.02-2.11</td>
<td>0.03</td>
</tr>
<tr>
<td>HDL Cholesterol (mg/dl)</td>
<td>2.01</td>
<td>1.44-2.79</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Glucose (mg/dl)</td>
<td>1.13</td>
<td>0.77-1.66</td>
<td>0.51</td>
</tr>
<tr>
<td>Insulin (µU/ml)</td>
<td>2.05</td>
<td>1.16-3.62</td>
<td>0.01</td>
</tr>
<tr>
<td>Insulin Resistance Index (HOMA-IR)</td>
<td>1.43</td>
<td>0.78-2.62</td>
<td>0.23</td>
</tr>
</tbody>
</table>

*Bottom tertile vs. the rest for HDL cholesterol. Tertiles were age-, race- and sex-specific. Models were age-, race- and sex-adjusted. All variables were included in both the models.

From: Mokha et al. BMC Pediatrics 2010, 10:73
Among healthy weight, those with high WHtR had increased odds of CMR risk.
Among Overwt/Obese, those with low WHtR had reduced odds of CMR risk.

From: Mokha et al. BMC Pediatrics 2010, 10:73
Waist v.s BMI As Long Term Predictors Of Risk

- 342 children measured at age 8y and a subset of 290 were reevaluated at age 15y
  - At age 15y, 9.4% to 11.0% had CVD risk clustering
  - 31.7% were overweight or obese
  - 20.0% had increased central adiposity.
Waist v.s BMI As Long Term Predictors Of Risk


- Odds Ratio for CVD risk clustering at age 15 based upon measurements at age 8y:
  - 6.9 (95% CI:2.5, 19.0) if overweight/obesity by BMI at age 8
  - 3.6 (95% CI:1.0, 12.9) if increased waist circumference at age 8, but not independent of BMI

- **BMI was the best long-term predictor of CVD risk**
Children Are Not Little Adults

Need consistent supporting evidence that visceral adipose tissue or waist circumference measurements offer significant improvement over BMI in identifying cardiometabolic complications of obesity in children.
Sagittal Abdominal Diameter (SAD)

- SAD was associated with dysglycemia (HbA1c concentration >5.7%) independent of age, and of waist circumference or BMI.
- Not widely used in children.
Sagittal Abdominal Diameter in Children

- 65 adolescents, ages 11-17y, referred for assessment of cardiometabolic risk.

SAD not superior to BMI, waist circumference or waist-to-hip ratio for detection of metabolic syndrome.
Dual Energy X-ray Absorptiometry

![Image of a body with Dual Energy X-ray Absorptiometry analysis](http://www.itnonline.com/sites/default/files/imagecache/node_image/photo_article/BodyMan250x503.jpg)

### Whole Body Fan Beam Analysis

*Image not for diagnostic use*

<table>
<thead>
<tr>
<th>Region</th>
<th>Fat (g)</th>
<th>Lean+BMC (g)</th>
<th>Total (g)</th>
<th>%Fat (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L Arm</td>
<td>1205.0</td>
<td>3685.3</td>
<td>4890.3</td>
<td>24.6</td>
</tr>
<tr>
<td>R Arm</td>
<td>1203.9</td>
<td>3902.3</td>
<td>5105.2</td>
<td>23.6</td>
</tr>
<tr>
<td>Trunk</td>
<td>8246.8</td>
<td>31777.5</td>
<td>40024.2</td>
<td>20.6</td>
</tr>
<tr>
<td>L Leg</td>
<td>3683.0</td>
<td>11385.1</td>
<td>15068.1</td>
<td>24.4</td>
</tr>
<tr>
<td>R Leg</td>
<td>3794.4</td>
<td>11755.3</td>
<td>15549.8</td>
<td>24.4</td>
</tr>
<tr>
<td>Sub Tot</td>
<td>18133.0</td>
<td>62505.5</td>
<td>80638.6</td>
<td>22.5</td>
</tr>
<tr>
<td>Head</td>
<td>1087.4</td>
<td>4159.0</td>
<td>5276.4</td>
<td>20.6</td>
</tr>
<tr>
<td>TOTAL</td>
<td>19220.4</td>
<td>66694.5</td>
<td>85915.0</td>
<td>22.4</td>
</tr>
</tbody>
</table>

Delphi A  SN 45775

Version 11.2.3  01/29/2003 09:33
Figure 2. Selected percentiles of smoothed percentage body fat among boys aged 8–19 years: United States, 1999–2004

Figure 3. Selected percentiles of smoothed percentage body fat among girls aged 8–19 years: United States, 1999–2004

Ogden et al. National Health Statistics Report 43(9), 2011
DXA Fat Mass & Lean Mass Index Reference Ranges For U.S. Children

- Age and sex patterns
- Total body fat mass index \([\text{fat mass (kg)/height(m)}^2]\)
- Lean body mass index \([\text{lean body mass (kg)/height(m)}^2]\)
Comparison Of FMI And BMI To Identify Metabolic Syndrome

- NHANES 1999–2006 data on 3004 participants, aged 12–20y with DXA and biomarkers of metabolic syndrome.
- FMI and LBMI were similar but not better than BMI in identifying metabolic syndrome

<table>
<thead>
<tr>
<th></th>
<th>AUC from unadjusted models</th>
<th>AUC for adjusted models</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI-Z</td>
<td>0.867 (0.846, 0.887)</td>
<td>0.890 (0.866, 0.910)</td>
</tr>
<tr>
<td>FMI-Z</td>
<td>0.868 (0.847, 0.885)</td>
<td>0.887 (0.863, 0.905)</td>
</tr>
<tr>
<td>LBMI-Z</td>
<td>0.823 (0.797, 0.848)</td>
<td>0.857 (0.833, 0.879)</td>
</tr>
<tr>
<td>FMI-Z + LBMI-Z</td>
<td>0.869 (0.848, 0.889)</td>
<td>0.890 (0.867, 0.910)</td>
</tr>
</tbody>
</table>
Survivors of childhood allogeneic hematopoietic stem cell transplantation (n=54) compared to reference group

- BMI-Z was the same, but lower lean mass and more fat mass than reference group
- LM and FM not associated with treatment or endocrinopathies after alloHSCT

Figure. LM-Ht and FM-Ht Z-scores in subjects with alloHSCT adjusted for height and age. LM* denotes further adjustment for FM-Ht Z-score.

Summary

- BMI is the simplest method to identify excess adiposity.
- Waist circumference or waist to height ratio may provide additional information about metabolic risk, but results are not fully consistent.
- Standardized procedures for measuring waist circumference are needed.
Summary

- Advanced body composition techniques are not consistently better than BMI in identifying cardiometabolic risk
- “Children are not little adults”
  - Measures such as sagittal abdominal diameter and visceral adipose tissue don’t show the same association with cardiometabolic risk in children as they do in adults
  - Developmental changes from birth to adulthood rarely considered and may be important
Findings regarding BMI as a screening tool from studies of healthy children may not be applicable to children with chronic illnesses at increased risk of altered body composition and cardiometabolic risk.
THANK YOU FOR YOUR ATTENTION!

Image from: https://s-media-cache-ak0.pinimg.com/736x/ca/48/53/ca48532027cc8bbd0c1de68b0be38f07.jpg