Welcome to the COPE Webinar Series for Health Professionals!

May 3, 2017

Measuring excess adiposity in children: What’s the best method?

12 noon - 1 PM EDT
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Handouts of the slides are posted at: www.villanova.edu/COPE

MacDonald Center for Obesity Prevention and Education (COPE) - Goals

Nursing/College Student Education
Continuing Education Programming
Research

Measuring excess adiposity in children: What’s the best method?

Objectives:
1. Gain a working knowledge of the changes in body composition that occur from birth to adulthood.
2. Understand the strengths and weaknesses of various body composition methods in children.
3. Identify the optimal method for body composition assessment in different patient populations in research and clinical care.

CE Credits

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• The American College of Sports Medicine's Professional Education Committee certifies that Villanova University College of Nursing Continuing Education, Center for Obesity Prevention and Education (COPE) meets the criteria for official ACSM Approved Provider status (2015-December, 2018). Providership #698849

CE Credits

• This webinar awards 1 contact hour for nurses and 1 CPEU for dietitians
• Suggested CDR Learning Need Codes: 3010, 3030, 5070, and 5370

Babette Zemel, Ph.D.
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Director, Nutrition and Growth Laboratory
Children’s Hospital of Philadelphia
University of Pennsylvania Perelman School of Medicine

Measuring excess adiposity in children: What’s the best method?
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Measuring excess adiposity in children – what’s the best method?

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Overview

- Have a working knowledge of the changes in body composition that occur from birth to adulthood
- Understand the strengths and weaknesses of various body composition methods in children
- Be able to identify the optimal method for body composition assessment in different patient populations in research and clinical care

Disclosures

- Nothing to disclose

Relative proportion of body compartments changes through the life cycle

Percent body fat (%BF) changes during infancy

Comparison of %BF in boys and girls, ages 0.5 to 24 mo (CNRC vs Fomon model)

Rapid increases in first few months

Girls>boys

Adapted from Holliday MA 1986; Body composition and energy needs during growth. From Human Growth, edited by Falkner F and Tanner JM

BUTTE, NANCY; KOPROWSKI, ADOLPH; NONO, WILLIAM; SMITH, E; ELLIS, KENNETH
DXA percent body fat reference ranges for children

- Males have a prepubertal spurt in percent body fat, and then decline as puberty advances.
- Females increase steadily in percent body fat

Ogden et al. National Health Statistics Report 43(9), 2011

Cautionary note on percent body fat

- %BF does not provide information about the absolute amount of fat mass or the amount of lean mass
- Minnesota Starvation Experiments showed that %BF is preserved even during starvation

Children with the same %BF can have a very different BMI Z-score

Unpublished data from the Bone Mineral Density in Childhood Study

DXA fat mass & lean body mass index reference ranges for U.S. children

- Fat mass index (FMI) and lean body mass index (LBMI) indicate size of tissue depot relative to skeletal size rather than body weight
- Males and females both increase with age in distinct patterns

Complications of excess adiposity

- 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)
Body Mass index (Weight/Height²)

- Dependent on accurate measurements – especially for height (or length)
  - Accurate stadiometer for measuring height by trained personnel
  - Removal of heavy outer clothing, shoes and hair adornments
  - Proper positioning of the head and body for accurate measurement
  - Measurement error in height is “squared” in BMI

High BMI is a good indicator of excess adiposity

- Fat mass index and 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

Strengths and limitations of BMI

- Strengths:
  - Low cost, non-invasive, widely available measure
  - Excellent reference data
  - Classification scheme for overweight and obesity
  - Correlates with other indicators of excess adiposity

- Weaknesses:
  - Doesn’t distinguish between fat and lean mass
  - Doesn’t measure fat distribution – “harmful fat”
  - Association of BMI and fatness varies with age
  - Influenced by pubertal maturation and population ancestry

Other anthropometric measures

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

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

Freedman and Sherry Pediatrics 2009;124:S23–S34

Freedman and Sherry Pediatrics 2009;124:S23–S34
Waist circumference measurement sites

- Other sites:
  - Natural waist (minimum)
  - NIH Multi-Ethnic Study of Atherosclerosis (MESA) study: level of the umbilicus or navel

Other anthropometric measures

- Strengths
  - Low cost
  - Minimal risk
  - Portable methodology
  - Spans all ages
  - Provide more information about amount of fat and fat distribution

- Limitations
  - Requires greater level of skill than BMI
  - Skinfolds unreliable in obese children
  - Doesn’t distinguish between subcutaneous and intra-abdominal fat depots
  - Modesty
  - Different measurement protocols and reference data for waist circumference

Other anthropometric measures

- Sagittal abdominal diameter
- Measures body depth at level of lumbar vertebrae 4-5
- Correlates with intra-abdominal fat in adults and dysglycemia (Kahn et al. 2014)
- Value for use in children uncertain

Densitometric Methods

- Density = mass/volume
- Conversion formulas assume constant densities of FM and FFM
- Density of FFM varies in children, elderly, African Americans, disease states
- Hydration of FFM increases with adiposity

Densitometric techniques

- Advantages
  - Rapid, safe, non-invasive
  - ADP can measure across broad age range (but limited for toddlers and physical or cognitive disabilities)
  - Accurate and precise

- Limitations
  - Equipment has a large footprint and is expensive
  - Requires bathing suit, subject time, training to complete test
  - Assumptions about air in body (lungs, intestines) and density of FFM
  - No tubes, leads, etc.
Isotope Dilution Methods

- Usually for measuring total body water (TBW), extracellular and intracellular water
- Stable isotopes: naturally occurring, safe
- Deuterium oxide (\(\text{H}_2\text{O}\))
- Oxygen-18 (expensive, but accurate)
- NaBR (extracellular water)

Stable Isotope Technique

- Naturally occurring isotopes \(\text{H}_2\text{O}\) and \(\text{H}_2\text{O}\)
- Baseline urine/saliva sample obtained to measure background quantities of isotopes
- Oral dose administered to enrich total body water stable isotopes
- Elimination of isotopes over time occurs through respiration and water loss

Isotope dilution

- Advantages:
  - Considered a criterion (gold-standard) method
  - Useful for all ages, and most disease states
  - One of a few possible methods for toddlers
  - Free-living conditions (field or clinical setting)
- Limitations:
  - Lab analysis and some isotopes are costly
  - Requires careful attention to measurement protocol
  - Accurate determination of dose
  - Results delayed
  - Assumptions about distribution of TBW in body

Bioelectrical Impedance Analysis

- Electrical current flows through the body by the movement of ions through body fluids.
- Impedance of a small electrical current passing through the body is proportional to the water and electrolytes in the body

Bioelectrical impedance analysis

- Advantages
  - Relatively inexpensive
  - Small space requirement
  - Minimal training
  - Rapid assessment
  - Good for population surveys
- Disadvantages
  - Proprietary predictions equations
  - Doesn’t perform better than using height and weight to estimate body composition
  - Standardization of body position, hydration status, consumption of food and beverages, skin and room temperature, and recent physical activity needed

Dual Energy X-ray Absorptiometry (DXA)

- Assumes the thickness, density and chemical composition of a tissue affects the attenuation of an energy beam
- DXA uses two energy beams of differing intensity to simultaneously solve for two tissue compartments.

Dual Energy X-ray Absorptiometry

- X-ray Source
  (produces 2 photon energies with different attenuation profiles)
- Collimator
  (pinhole for pencil beam, slit for fan beam)
- Detector
  (detects 2 tissue types - bone and soft tissue)
Dual energy x-ray absorptiometry (DXA)

- **Visceral adipose tissue**
- **Indices of fat distribution**
  - Android/gynoid
  - Trunk/limb fat ratio
- **Fat mass index**
- **Indices of lean mass**
  - Lean mass index
  - Appendicular lean mass index

**Advantages**
- Measure 3 compartments (fat mass, lean body mass, bone mass)
- Rapid (3 minutes), safe (low x-ray exposure), excellent precision
- Can be used for infants, children, adults
- Provides regional and whole body measures
- NHANES reference data for Hologic DXA

**Limitations:**
- Comparability across models, manufacturers, software versions
- Pregnancy test required for females with reproductive potential
- Cost and space
- Size and composition of marrow space and head not measured
- Metal implants/movement artifact

Magnetic Resonance Imaging & Spectroscopy

- MRI generates three-dimensional images to quantify volume and distribution of anatomic structures
- MRS measures molecules or products of metabolism such as amino acids, lipids, lactate, choline and creatine.

Intramyocellular and extramyocellular lipid

- Determination of intramyocellular lipids (IMCL) in tibialis anterior (TA) and soleus muscle (SOL).
  - (a) the T1-weighted image
  - (b) Spectrum of tibialis anterior muscle (TA)
  - (c) Spectrum of soleus muscle (SOL)

From Machann et al. MAGMA (2005) 18: 128-137

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.
MRI / MRS body composition measures

- Strengths
  - Non-invasive
  - Measures size and distribution of tissues/organisms
  - Measures composition at tissue level

- Limitations
  - Expense and availability
  - Useful in research setting
  - Body composition measures not used clinically (screening, diagnosis, treatment)

Complications of excess adiposity

- 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?

Visceral vs subcutaneous fat

- 28 healthy weight and 44 obese adolescents
- Visceral adipose tissue volume increases exponentially as BMI increases

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

Which is the best waist circumference measurement site?

  - 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

Waist circumference vs BMI in predicting insulin resistance

<table>
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<th>Model Independent Variable</th>
<th>Beta</th>
<th>SE</th>
<th>p</th>
<th>R²</th>
<th>Model number</th>
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<td>0.018</td>
<td>0.207</td>
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<tr>
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<td>0.118</td>
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<tr>
<td>Pubertal Status</td>
<td>-0.258</td>
<td>0.085</td>
<td>0.003</td>
<td>0.22</td>
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<td>-0.258</td>
<td>0.085</td>
<td>0.003</td>
<td>0.22</td>
</tr>
<tr>
<td>BMI percentile</td>
<td>-0.251</td>
<td>0.065</td>
<td>&lt;.001</td>
<td>0.30</td>
<td>WC</td>
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<td>and WC</td>
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<td>-0.230</td>
<td>&lt;.001</td>
<td>0.56</td>
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<td>-2.772</td>
<td>-0.230</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 Peds* 2006;148:188-94)
Waist to Height Ratio vs BMI

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 (Systolic or Radial)</th>
<th>BM</th>
<th>WHtR</th>
<th>OR (95% CI)</th>
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<tbody>
<tr>
<td>BMI</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00 (0.87, 1.16)</td>
</tr>
<tr>
<td>WHtR</td>
<td>1.01</td>
<td>1.05</td>
<td>1.02 (0.97, 1.06)</td>
</tr>
</tbody>
</table>

Among normal weight, those with high WHtR had increased odds of CMR risk.

Waist vs BMI as long term predictors of risk

- 342 children measured at age 8y and a subset of 290 were reevaluated at age 15y.
- OR for CVD risk clustering at age 15:
  - 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

Sagittal abdominal diameter (SAD)

- 65 teen, 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

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 (Weber et al. JCEM 2014)
- FMI and LBMI were similar but not better than BMI in identifying metabolic syndrome
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

Body composition in special populations

- 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

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

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- CHOP Clinical and Translational Research Center
- Gail Jackson and the Nutrition Core Lab
- CHOP Nutrition Center
- CHOP Research Institute
Thank you for your attention!


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- The email will be sent to the email address that you used to register for the webinar.
- Complete the evaluation soon after you receive the email. The evaluation does expire after 3 weeks. Once expired, you cannot obtain a certificate.
- Once the evaluation is completed, the certificate will be emailed separately within 2 or 3 business days.

Upcoming FREE COPE Professional Webinar

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Assistant Professor of Psychology
Director of Clinical Services
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Can Acceptance and Commitment Therapy (ACT) Improve Adherence to Weight Loss Goals?

Monday, June 26, 2017
12:00 PM - 1 PM EST
1.0 Contact Hour, 1.0 CPEU

To register: villanova.edu/cope

Questions and Answers

Moderator: Lisa K. Diewald MS, RD, LDN
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