Beyond the Scale: Infant Body Composition Techniques and Implications for Practice

DATE: 9/10/24 PRESENTED BY: Maggie Jerome, PhD, RD Assistant Professor Oregon Health & Science University

Commercial support has been provided by Nutricia North America

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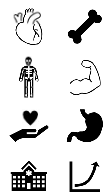
Objectives



- Review normal body composition during infancy
- Describe methods for body composition assessment in infants and their value in nutrition assessment
- Summarize outcomes associated with body composition patterns in term infants

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Infant Body Composition Assessment

- A tool to **track growth** and ensure that infants receive adequate nutrition.
- Body composition in infants is associated with future **growth, metabolic health, and neurodevelopmental** outcomes

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How is body composition affected during infancy?

Water content is higher and distribution of water shifts between extracellular and intracellular spaces changes across time

- 75% of body weight at birth is water
- 5-10% of body weight lost in days following birth (mostly water)
- Extracellular water decreases and intracellular water increases across childhood
- Affects hydration of fat-free mass

4
(Zemel, 2022)

4

How is body composition affected during infancy?

Rapid gains in body fatness for first 3-6 months of life

- Average percent body fat at 6 months is 29.1% in boys and 32.0% in girls

Brown adipose tissue is higher in infants than in children and adults

- Brown adipose tissue is highly metabolically active
- Helps infants maintain body temperature

5
(Zemel, 2022)

5

How is body composition affected during infancy?

Organ tissue makes up a greater proportion is mass at birth and decreases over time

- Heart, lung, liver, brain and other organs make up a large percentage of body mass
- Example: the brain makes up 13% of body weight at birth, which decreases to roughly 2% in adulthood

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(Zemel, 2022)

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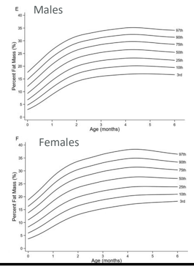
How does body composition change across infancy?

We can visualize trends in body composition utilizing published body composition reference curves



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(Murphy-Alford et al, 2023)

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Why not just use BMI or weight-for-length?

BMI (Body mass index)
- Used as a proxy for body fatness and overall health status in pediatric/adult populations

Weight-for-length
- Clinically used to assess body proportionality

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Why not just use BMI or weight-for-length?

BMI and wt-for-length do not accurately reflect adiposity during rapid changes in lean mass and adiposity that occur in infancy

At birth:
Stronger correlation between BMI *Z* score/weight-for-length *Z* score and fat-free mass

By 5 months this correlation flips

At 5 months:
BMI *Z* score / weight-for-length *Z* score more strongly associated with fat mass

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(Perng, 2017)

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Body Composition Assessment

Body composition analysis also can provide information about the amount and distribution of:

- body fat
- lean body mass
- bone mineral content

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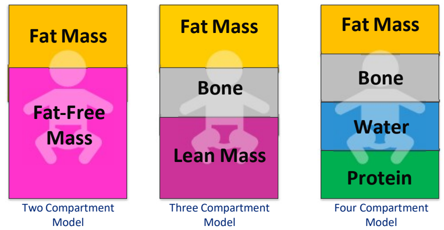
Body Composition Assessment



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Air Displacement Plethysmography

- **2 compartment** model (fat mass and fat-free mass)
- Fat mass and fat-free mass estimated from densitometry
- PeaPod© from Cosmed

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(Fomen, 1982)

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Air Displacement Plethysmography

Pros
- Quick
- Non-invasive
- Not affected by movement
- Reference curves available
- Popular choice for research studies

Cons
- Expensive
- Large equipment
- Requires trained technician
- Cannot determine regional fat
- Not validated in infants >6 months

Clinical Considerations
- Infants must be clinically stable
- Multiple assessments possible
- Can be used in infants 1-8kg
- Validated in term and preterm infants

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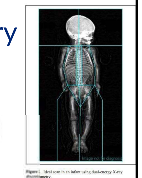
Dual X-ray Image Absorptiometry

- **3 compartment** model (fat mass, lean mass, bone mineral content)
- Attenuation of x-ray beams of 2 different energy levels in tissues



Source: Fields, 2015

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Dual X-ray Image Absorptiometry

Pros
- Measures regional adiposity
- Measures bone density
- Popular choice for research studies

Cons
- Small amounts of radiation exposure
- Large equipment
- Affected by movement
- Results differ by manufacturer

Clinical Considerations
- Infants must be clinically stable
- Number of scans may be limited in infancy
- No reference curves for regional measurements

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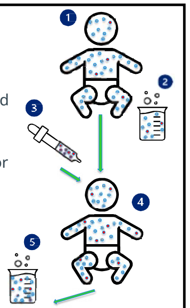
Isotope Dilution

- **2 compartment** model (fat-free mass and fat mass)
- A stable (nonradioactive) isotopically-labeled water such as deuterium oxide or oxygen-18 hydride, and is provided
- Calculate total body water using the dilution principle
- Fat-free mass estimated using hydration factors



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Isotope Dilution

Pros

- Straightforward procedure
- Highly reliable / accurate
- Can be utilized throughout the lifespan

Cons

- Time consuming
- Samples must be analyzed in a lab
- Assumptions include hydration factors, which are changing throughout infancy
- Cannot determine regional fat

Clinical Considerations

- Delayed results for provider / parent
- Patients must be present for initial sample collection, equilibration period, and second sample collection
- Could be used in critically ill infants

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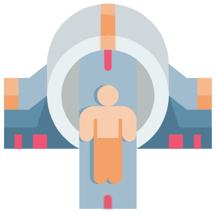
Magnetic Resonance Imaging

- **3-compartment** (fat mass, lean mass, skeletal muscle mass)
- Tissue density assessed from cross-sectional images



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Magnetic Resonance Imaging

Pros
- Highly accurate
- Quick in infant
- Can assess regional adiposity and visceral adipose tissue
- No radiation exposure

Cons
- Expensive
- Requires highly specialized equipment and expertise
- May require sedation
- More difficult in older infants due to movement

Clinical Considerations
- Requires access/transport to MRI machine
- Difficult in critically ill and older infants
- Cost

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Skinfold Thickness

- **2-compartment** (fat-free mass and fat mass)
- Measuring thickness of skin and fat at specific location using calipers at 4 sites
- Calculate FM and FFM using predictive equation

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Skinfold Thickness

Pros
- Easy
- Low cost
- Portable

Cons
- Questionable accuracy
- Variability between observers

Clinical Considerations
- Difficult in premature infants or infants with minimal subcutaneous fat
- Same person should take measurements across time

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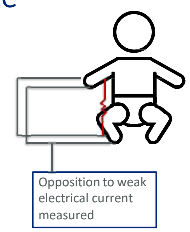
Bioelectrical Impedance

- **2-compartment** (fat-free mass estimated from total body water and fat mass)
- Estimation of FFM from tissue impedance to weak electrical current



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Bioelectrical Impedance

Pros
- Easy
- Low cost
- Portable
- Quick

Cons
- Poor predictive performance in infants
- Requires further validation
- Cannot determine fat distribution

Clinical Considerations
- Feasible in clinically ill infants
- Could repeat measures over time

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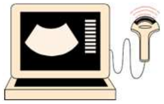
Ultrasound

- Tissue echogenicity
- Subcutaneous fat thickness, muscle thickness, and BMC



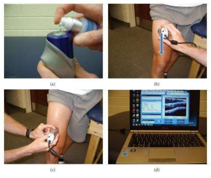


Image: Wagner (2013)

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Ultrasound

Pros
- Quick
- Portable
- Frequently available at bedside

Cons
- Poor predictive performance in infants
- Requires further validation
- Results dependent on technique

Clinical Considerations
- Validated equations needed
- Reference values required before being clinically useful
- Potential for inconsistency in measurement

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Why assess body composition in infancy?

- Assess nutrition status
- Insight into future health

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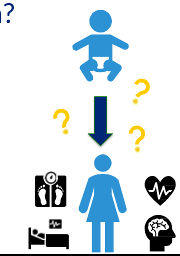
How is body composition in infancy associated with later health?

- Limited evidence due to recent developments in body composition assessment
- Strongest associations between body composition and later growth, adiposity, and obesity



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Body composition at birth

- Body composition at birth may provide insight into **intrauterine conditions** and future risk for cardiovascular disease
- **Inverse associations** between both **fat mass** and percent body fat at birth and **blood pressure trajectories** at 3–6 years of age.

Source: National Institute of Diabetes and Digestive and Kidney Diseases, National Institutes of Health

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(Ong, 2022)

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Longitudinal Studies Suggest a Link Between Infant Adiposity and Later Adiposity and Growth

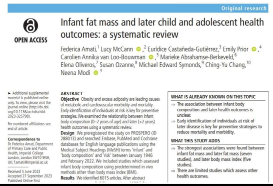

Table 2 Overview of the associations between infant fat mass and later health outcomes and health biomarkers

Health outcomes	Fat mass/adiposity in infancy		
Outcome Variable	Increase	No relationship	Decrease
FM	7 [illegible]	3 [illegible]	
FFM	1 [illegible]	2 [illegible]	
BMI	5 [illegible]	3 [illegible]	
Blood pressure	2 [illegible]	5 [illegible]	
T1DM		1[45]	
Adiponectin		1[22]	
Resistin		1[22]	
Leptin	1[22]		
Fasting glucose	1[25]	2[6 26]	1[37]
Insulin	1[25]	3[25 6 24]	
HDL	1[6]	1[24 26]	1[37]
C-peptide		1[6]	
HbA1c		1[6]	
LDL	1[6]	1[26]	1[24**]
Triglycerides		4[25 26 6 24]	
Total cholesterol	2[25 6]	1[26 24]	
HOMA-IR (insulin resistance)	1[25]	2[26 6]	
Lung function and asthma		1[46]	
Cognitive function/ processing speed		1[26 27]	
P100 Latency		1[27]	

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Gains in fat-free mass and fat mass during infancy predict later body composition

Fat-free mass accretion predicts fat mass index at 4 years

Fat mass accretion predicts fat mass index at 4 years

Table 3 Association of early infancy standardized tissue accretion rates with fat-free mass index (FFMI, kg/m^2) and fat mass index (FMI, kg/m^2) at 4 years of age in the iABC cohort study ($n = 307$)

Tissue accretion rate	Model 1[a]	Model 2[b]	Model 3[c]
FFMI (kg/m^2) at 4 years			
FFM (0–6 months)	0.20 (0.06, 0.33)**	0.21 (0.09, 0.33)***	0.24 (0.11, 0.36)***
FM (0–4 months)	−0.02 (−0.15, 0.11)	−0.01 (−0.14, 0.12)	−0.01 (−0.14, 0.12)
FMI (kg/m^2) at 4 years			
FFM (0–6 months)	0.21 (0.04, 0.38)*	0.19 (0.03, 0.35)*	0.20 (0.04, 0.37)*
FM (0–4 months)	0.29 (0.11, 0.47)**	0.30 (0.12, 0.48)***	0.30 (0.12, 0.47)***

Each row shows separate multiple linear regression result for the outcome (FM and FFMI). Slope estimates (β) shown with 95% confidence interval

[a]Model 1: accretion rates (FFM or FM accretion rates) adjusted for length accretion rate, sex of the child, birth order, FFM or FM at birth, and child age at 4 years

[b]Model 2: as model 1, further adjusting for parental characteristics (baseline maternal age, maternal education, parental wealth index, and maternal postnatal BMI) measured at 1.5–6 months postpartum

[c]Model 3: as model 2, further adjusting for breastfeeding at 3.5 (±1 months) postpartum and stunted (yes/no) at 4 years

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

Body composition during early infancy and its relation with body composition at 4 years of age in Jimma, an Ethiopian prospective cohort study. Admassu B, et al. http://creativecommons.org/licenses/by/4.0/. CC By 4.0. No changes were made.

30

(Admassu, 2018)

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(Admassu, 2018)

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Gains in fat-free mass and fat mass during infancy predict later body composition

- Similar patterns in other cohort studies
- Tracking of body composition through childhood may be differ by infant feeding type

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ORIGINAL ARTICLE

Pediatric Obesity

Fat mass and fat-free mass track from infancy to childhood: New insights in body composition programming in early life

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Abstract

Objective: Early life is a critical window for adiposity programming. This study investigated whether fat mass percentage (FM%), fat mass index (FMI), abdominal fat, and fat-free mass (FFM) in early life track into childhood and whether there are sex differences and differences between infant feeding types.

Methods: Detailed body composition was longitudinally measured by air-displacement plethysmography, dual-energy x-ray absorptiometry, and abdominal ultrasound in 224 healthy, term-born children. Measurements were divided into tertiles. Odds ratios (OR) of remaining in the highest tertile of FM%, FMI, abdominal subcutaneous and visceral fat, and FFM index (FFMI) were calculated from early life to age 4 years.

Results: High FM% and FMI tracked from age 3 and 6 months to age 4 years (OR = 4.34 [$p = 0.002$] and OR = 6.54 [$p < 0.001$]). High subcutaneous abdominal fat tracked from age 6 months to age 4 years (OR = 2.30 [$p = 0.012$]). High FFMI tracked from age 1, 3, and 6 months to age 4 years (OR = 4.16 [$p = 0.005$], 3.71 [$p = 0.004$], and 3.36 [$p = 0.019$]). In non-exclusively breastfed infants, high FM% tracked from early life to age 4 years, whereas this was not the case for exclusively breastfed infants. There was no tracking in visceral fat or sex differences.

Conclusions: Infants with high FM%, FMI, subcutaneous abdominal fat, and FFMI in early life are likely to remain in the highest tertile at age 4 years. Exclusive breastfeeding for 3 months is potentially protective against having high FM% at age 4 years.

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(van Beijsterveldt, 2021)

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Gains in fat mass during infancy predict childhood overweight/obesity

Each 100-g/month increase in fat mass gain was associated with eightfold odds of childhood overweight or obesity

Association between weight gain in infancy (0-8 months) and childhood overweight/obesity status.

Variable	OR	95% CI	*P*-value
Total weight gain (100 g/month-1)	4.76	1.05-21.5	0.04
Fat mass gain (100 g/month-1)	8.03	1.11-58.2	0.04
Lean mass gain (100 g/month-1)	5.06	0.71-36.2	0.11

Adjusted for birth weight and maternal education (categorical). Age and gender were not included because they are already incorporated into the definition of the outcome variable (body mass index percentile-based overweight/obesity status). CI, confidence interval; OR, odds ratio.

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(Koontz et al, 2014)

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Mixed Results and Insufficient Evidence Between Infant Adiposity and Metabolic Outcomes

Original research

OPEN ACCESS

Infant fat mass and later child and adolescent health outcomes: a systematic review

Federica Amati,[1] Lucy McCann,[2] Eurídice Castañeda-Gutiérrez,[3] Emily Prior,[4] Carolien Annika van Loo-Bouwman,[5] Marieke Abrahamse-Berkeveld,[6] Elena Oliveros,[7] Susan Ozanne,[8] Michael Edward Symonds,[9] Ching-Yu Chang,[10] Neena Modi[4]

► Additional supplemental material is published online only. To view, please visit the journal online (http://dx.doi.org/10.1136/archdischild-2023-325798).

For numbered affiliations see end of article.

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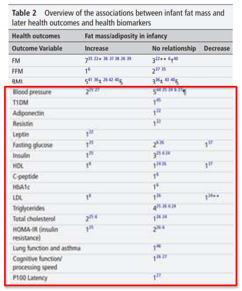
ABSTRACT
Objective Obesity and excess adiposity are leading causes of metabolic and cardiovascular morbidity and mortality. Early identification of individuals at risk is key for preventive strategies. We examined the relationship between infant body composition (0–2 years of age) and later (>2 years) health outcomes using a systematic review.
Design We preregistered the study on PROSPERO (ID 288013) and searched Embase, PubMed and Cochrane databases for English language publications using the Medical Subject Headings (MeSH) terms 'infant' and 'body composition' and 'risk' between January 1946 and February 2022. We included studies which assessed infant body composition using predetermined in vivo methods other than body mass index (BMI).
Results We identified 6015 articles. After abstract

WHAT IS ALREADY KNOWN ON THIS TOPIC
⇒ The association between infant body composition and later health outcomes is unclear.
⇒ Early identification of individuals at risk of later disease is key for preventive strategies to reduce mortality and morbidity.

WHAT THIS STUDY ADDS
⇒ The strongest associations were found between infant fat mass and later fat mass (seven studies), and later body mass index (five studies).
⇒ There are limited studies which assess other health outcomes.



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FFM	1[6]	2[37 35]	
BMI	5[41 36± 26 42 40§]	3[36± 43 40§]	
Blood pressure	2[25 27]	5[44 25 24 6 27¶]	
T1DM		1[45]	
Adiponectin		1[22]	
Resistin		1[22]	
Leptin	1[22]		
Fasting glucose	1[25]	2[6 26]	1[37]
Insulin	1[25]	3[25 6 24]	
HDL	1[6]	1[24 26]	1[37]
C-peptide		1[6]	
HbA1c		1[6]	
LDL	1[6]	1[26]	1[24**]
Triglycerides		4[25 26 6 24]	
Total cholesterol	2[25 6]	1[26 24]	
HOMA-IR (insulin resistance)	1[25]	2[26 6]	
Lung function and asthma		1[46]	
Cognitive function/ processing speed		1[26 27]	
P100 Latency		1[27]	

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Body Composition and Neurodevelopment

- Motor delay 2.32 times more likely in infants with high subcutaneous fat in a longitudinal study on 217 infants
- Inflammatory markers and hormone levels may affect brain development and function
  - IGF-1, leptin, and adiponectin.

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(Slining et al, 2010)

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Body Composition and Neurodevelopment

Fat-free mass status in infancy may also be predictive of neurodevelopment.

Fat-free mass at birth was associated with **higher global development score** at 2 years of age.

Fat-free mass at birth was associated with **decreased mental health problems** at 5 years

36
(Abera e al, 2017)

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Implications for Clinical Practice

- **Not yet the standard** of care in the clinical setting
- Increasing access to **noninvasive** body composition assessment techniques
- Clinicians will be able to **personalize care** to the specific needs of each infant based on their risk factors, individual growth, and nutrition status.

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What's next for infant body composition research?

- Need improved methods
- Need for more robust reference data for body composition comparison
- More nutrition intervention studies focused on at-risk populations

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Thank You

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