Co-organiser: UPM
5th ANNUAL GENERAL MEETING & SCIENTIFIC UPDATE 1/2024

Measuring body composition in children

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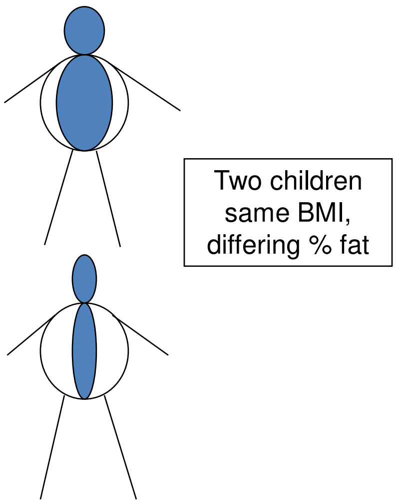
The problem with BMI

Cannot discriminate between fat and lean mass

Children with the same BMI can have widely differing body fat and lean, reflecting differences in musculature and build



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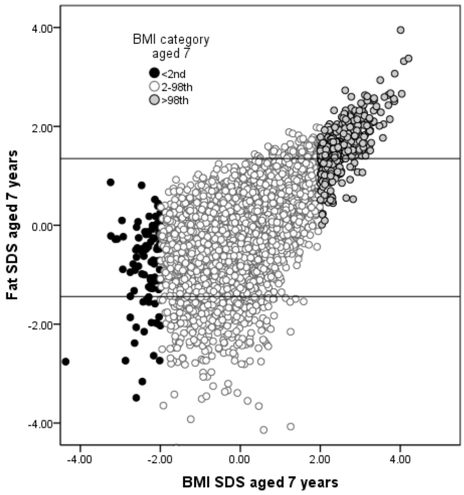
How BMI relates to body fat in childhood

- Good correspondence between high BMI and fat
- Very poor correspondence between low body fat and low BMI
- Most children with low BMI do not have low body fat



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Describing body composition

Number of compartments

1. Weight
2. Fat + fat-free (lean) mass
3. Fat + muscle + bone
4. Fat + muscle + bone + water

Adjustment for size

- BMI
- %Fat
  or lean and fat indices (÷ Height^2)

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Ways to measure body composition

- Underwater weighing
- Air displacement plethysmography
- MRI
- Stable isotopes
- Dual energy X-ray absorptiometry (DEXA)
- Bioelectrical impedance (BIA)
- Skinfolds
- Dissection

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Which of these measure body composition directly?

• Underwater weighing	X
• Air displacement plethysmography	X
• MRI	X
• Stable isotopes	X
• Dual energy X-ray absorptiometry (DEXA)	X
• Bioelectrical impedance (BIA)	X
• Skinfolds	X
• Dissection	√

Measuring body composition in living individuals must rely on indirect or incomplete measures

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Understanding body composition measures

- What physical principle do they exploit?
- What is actually measured?
- What assumptions do they make?
  - i.e. what do they not measure?
- Computation required
  - Always needed, but some are simpler, or more valid, than others

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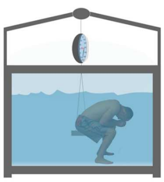
Measures of density: Air displacement plethysmography (& underwater weighing)



- Fat is less dense than lean
- Requires prediction equation using known density of lean and fat mass, lung volume and weight
- Measures obtained = % fat and lean
- Assumptions
  - That density of lean mass is constant
  - That lung volume is accurately estimated
- Only practical in children over 5 years or babies

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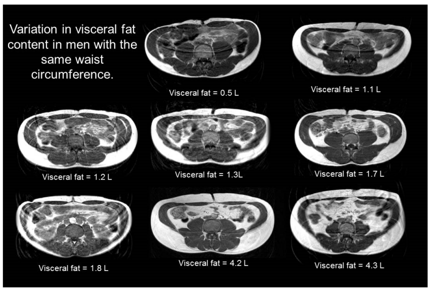
CT / MRI



- Fat absorbs X rays / resonates differently from bone and soft tissue
- Assumes that slices measured are representative of the total body
- Prediction equations generate
  - Skeletal muscle mass
  - Total, subcutaneous and visceral Adipose Tissue (SAT and VAT) mass
- CT not ethical in children
- MRI only practical in older children

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Measures of total body water (TBW)

- Total body water is proportionate to total fat free (lean) mass as fat contains no water
- Assumes hydration of fat free mass is constant
  - Fat free mass = TBW * hydration constant
  - Different constants for age and gender

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TBW via stable isotopes (Deuterium dilution, hydrometry)

- A consumed dose of stable isotope labelled water will be evenly distributed through the total body water within 3-5 hours and excreted in urine and saliva at the same dilution
  - Assumes that the labelled water is all consumed and not incorporated into other substances
  - Fairly simple maths
- Measures Fat free mass (FFM)
  - Fat mass by subtraction
- Practical in small children

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TBW via bioelectrical impedance

- The resistance (impedance) of a conducting substance to an alternating current is proportionate to its volume
- Assumes that the body is a perfect column
- $TBW \propto Height^2/Z$
  - Requires appropriate resistivity constant to adjust for varying body shape with age
- Measures fat free mass (FFM)
  - Fat mass by subtraction
- Practical in older children
  - Need big enough feet!

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Grip strength

- Proxy measure of functional muscle mass
- Powerful predictor of future health

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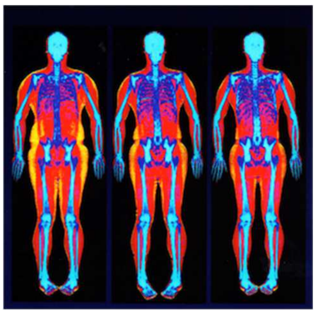
Dual energy X-ray absorptiometry (DEXA)



- Fat absorbs X rays differently from bone and soft tissue
- Assumes that the fat around the edge of the image is proportionate to the total fat mass (including visceral fat)
- Complex (machine) prediction equations needed
  - Adjustment required for body depth (size)
  - Robust for bone mineral content & density
  - Fair for lean mass
  - Weak for adipose tissue fat mass
- Feasible for older children who can lie still

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Skinfolds

- Subcutaneous fat layer can be measured between lifted fold of skin
- Assumes that the subcutaneous fat at the sample sites is proportionate to the total fat mass (including visceral fat).
- Skinfolds obtained need
  - Prediction equation to calculate %fat
  - Z scores for children
- Cheap and quite easy to measure in children
- "Salient"

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What are prediction equations for? (and what makes them good?)

- To create a useable estimate of a body composition element
  - Needs to be parsimonious
  - Needs to rely mainly on measured element
  - E.G. Lean mass = H/R * ($height^2$ / Z)
- To set the measure in the context of a valid reference population
  - Should only be specific to physiologically / anatomical distinct populations – male vs female, child vs adult
  - Needs to to allow comparison between populations
  - Between population differences most likely to reflect economic, dietary and environmental differences

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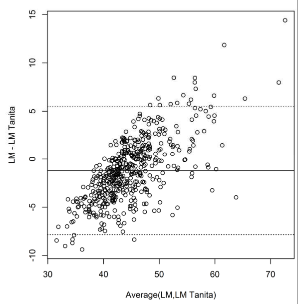
Be sceptical about machine generated calculations

- Prediction equations are commonloy adjusted for other measures and may make little use of BC measure
- E.G. Prediction equation used by Tanita for FFM in adult women relies on weight as well as height^2/Z
  - 1SD change in weight → lean mass estimate changes by 2.8kg
  - 1 SD change in impedance → lean mass estimate changes by only 1 g
- Why bother to measure impedance at all?

Limits of agreement between machine generated estimate for lean mass and researcher calculated using basic equation

(a)



(c)

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Which BC measure to use?

	Measures	Cost	Acceptability / feasibility	Use in field	Accuracy	Precision
Stable isotopes*	Lean mass	Expensive	Medium / low	Yes	High	Good
Air displacement plethysmography	Lean and fat mass	Expensive	Age dependent	No	High	Good
MRI / CT scanning	Lean and fat mass	Expensive	Medium	No	High	Good
DXA*	Bone	Quite expensive	Medium	No	Low	Good
BIA*	Lean mass	Cheap	High	Yes	Low	Medium
Skinfolds*	SC Fat	Cheap	Medium	Yes	Low	Medium
Waist circumference	Visceral fat	Free	High	Yes	Low	Low
Weight	Total mass	Cheap	High	Yes	Low	Good

* useable in young children

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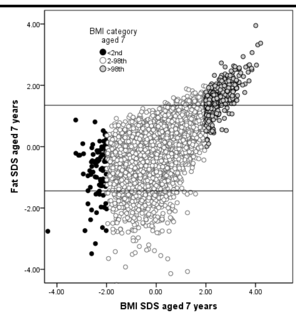
Composite measures



- For clinical use
  - BMI is often enough
  - For complex children use skinfolds to measure fat and lean using BIA or grip strength
- For research
  - Low cost: Skinfolds to measure fat, DEXA for FFM
  - Gold standard: 3 or 4 compartment models
    - Preschool children: deuterium dilution

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4 (3) Component model

- Minimizes assumptions by using method that most directly measures each component:
  - Body volume (BV)= underwater weighing or plethysmography
  - Total body water (TBW) = Deuterium
  - Body weight (BW) = Scales
  - Bone mineral content (BMC) = DXA

3 components:

Fat mass = (2.220 * BV) - (0.764 * TBW)] - (1.465 * BW)

4 components:

Fat mass = (2.747 * BV) - (0.710 * TBW)] + [(1.460 * BMC) - (2.050 * BW)

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Malaysian Society of Body Composition

Co-organiser: UPM

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Is early childhood obesity just a measurement artefact?

New finding from body composition studies and systematic reviews

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How common is childhood obesity?

The prevalence depends upon the threshold chosen!

Threshold	Definition	Glasgow children
>85th	Public health overweight	35%
>91st	UK chart and IOTF overweight	27%
>95th	Public health obese threshold	20%
>98th	UK chart clinically obese	13%
98-99.6	IOTF obese = Adult BMI 30	8%
>99.6th	UK chart severely obese	4%
>3.33 SD	UK chart morbidly obese	0.5%

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How were childhood overweight and obesity thresholds selected?

- Adult obesity and overweight thresholds were set on basis of their association with adverse health outcomes
- **Problem:** level of childhood BMI associated with increased later health risk is/was not clear
- **Work around chosen:** same upper BMI centile used to identify the same proportion of children at each age who were at risk of future overweight /obesity
  - Now synonymous with "overweight " and "obesity"
- But how plausible is it that prevalence of obesity was ever constant at all ages?

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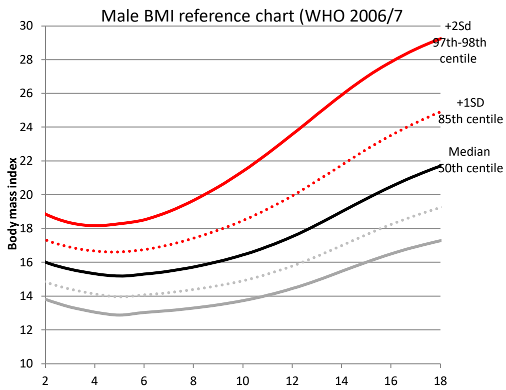
Problems with thresholds based on upper centiles

- Hard to define outer limits of any distribution robustly
  - tiny numbers at extremes
- BMI data are strongly skewed



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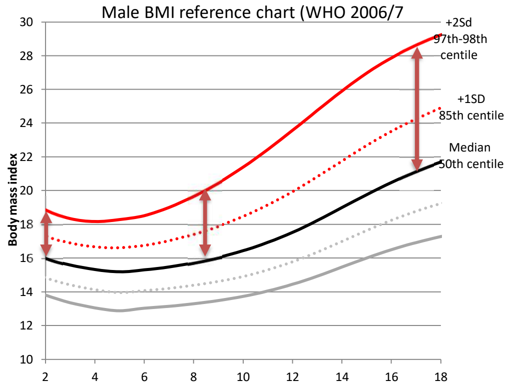
Problems with thresholds based on upper centiles

- Upper limits vary much more with age than average values



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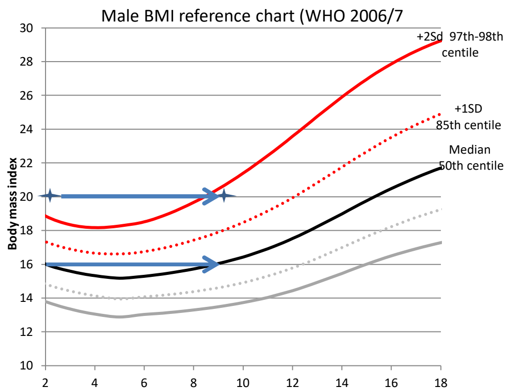
Problems with thresholds based on upper centiles

- Young children cross upper thresholds with much lower BMIs than older children, even where median BMI is the same
- BMI 20
  - age 2 years Z=3.1
  - age 9 years Z=1.8
- But both are 25% above same median for age



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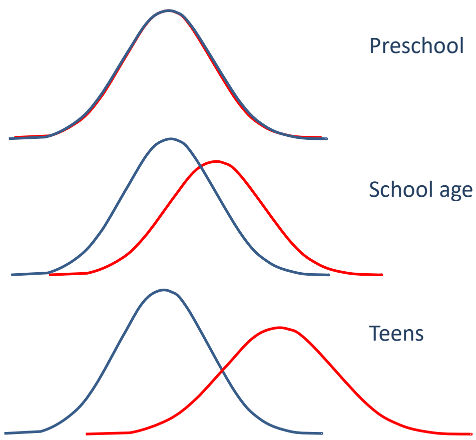
Why does BMI curve become more skew with age?

Obesity develops over time in response to obesogenic environment in susceptible individuals



Preschool
- Few infants initially have excess fat, so both susceptible and non susceptible have near normally distributed BMI

School age
- More and more susceptible individuals become overweight, stretching upper bounds and introducing skew

Teens
- Susceptible individuals become more and more overweight, increasing upper limits, while non susceptible remain normally distributed

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Proposition

- Centile based thresholds for BMI based on extremes of reference growth data lack biological validity
- Upper centiles reflect varying prevalence of obesity, not range of true health
- What is ideally needed is a standard for the healthy range of childhood BMI

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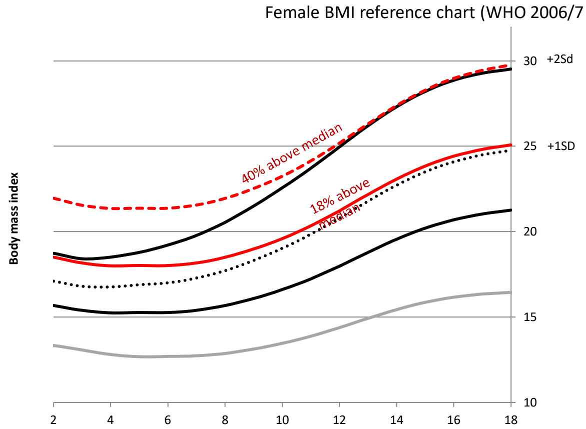
A new definition of obesity?

- Median varies less with age and is constant between countries & eras
- Would a constant % above median be more valid than a constant centile?

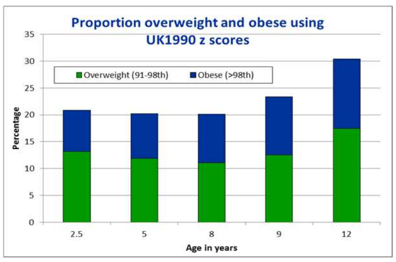


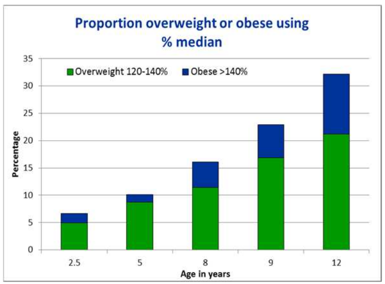
At age 18
BMI 30 is 40% above median
BMI 25 is 18% above

These can be back extrapolated to form thresholds for healthy BMI

Effect of using %median BMI metric

BMI centiles and % median compared using data from Gateshead Millennium cohort





Centile thresholds

- Prevalence of overweight and obesity very similar at young ages
- Rises in later childhood =secular trend to increasing obesity since standards set.

% median

- Obesity very rare <age 8
- Rises steeply with age to similar prevalence in teens as for centile thresholds

Questions still to be answered

- If centile based thresholds are truly over-diagnosing obesity at young ages
  - High body fat should be rare in younger children
  - For any given BMI centile younger children should have lower body fat than older children
  - Obesity at young ages should have fewer negative health consequences

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Body composition data show that high body mass index centiles over-diagnose obesity in children aged under 6 years. American Journal of Clinical Nutrition. 2021
Wright, C. M., T. J. Cole, M. Fewtrell, J. E. Williams, S. Eaton and J. C. Wells

- Used uniquely-large database of body composition measures collated by Jonathan Wells at UCL
- Includes data from >2500 UK individuals aged from 6 weeks to 20 years
  - Mostly normative data
  - Supplemented with data from obesity clinics to look at extremes of fat mass
  - Relatively sparse data on younger children, mostly quite old
- Fat and lean estimated using gold standard methods
  - 4 component for children >5
  - Stable isotopes only for children <5 years
- Fat and lean mass adjusted for height using division by $Height^2$ to give FMI and LMI

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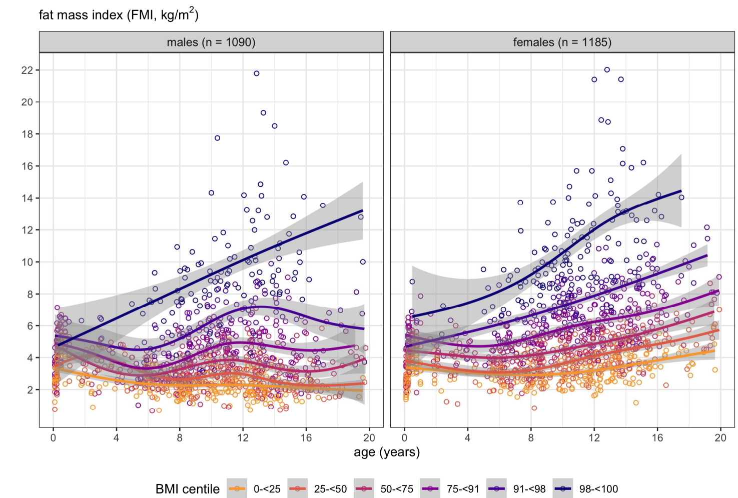
Is high FMI rare in younger children?

- Very few younger children had raised FMI
- FMI equivalent to BMI 91-98th and >98th much lower at younger ages
- Confidence intervals between centile categories widely overlap until age 6



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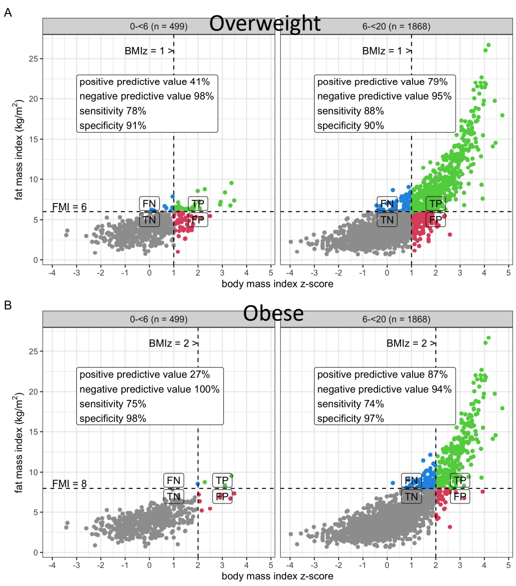
Does a high BMI reliably detect high body fat?

FMI 6 and BMI 1SD used for overweight & obese (OWOB)
FMI 8 and BMI 2SD for obese

- **Under age 6**
- BMI >1SD identifies 78% children with FMI >6
- BMI >2SD identifies 75% children with FMI >8
- But a majority (59-73%) are false positives

= Overdiagnosis



After age 6
- BMI >1SD identifies 88% with FMI>6
- BMI >2SD identifies 74% with FMI>8
- Only a minority (21-13%) are false positives

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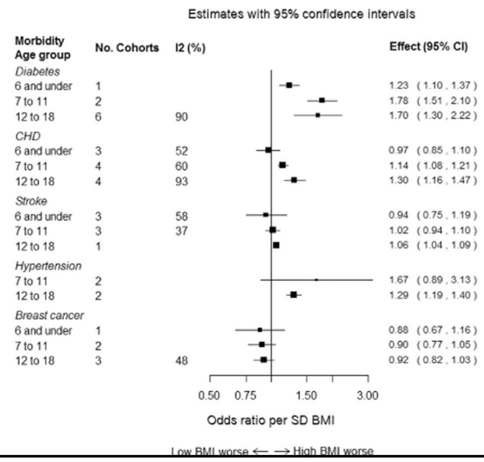
Does obesity at young ages have fewer negative health consequences?

Llewellyn, A., M. Simmonds, C. G. Owen and N. Woolacott (2016). "Childhood obesity as a predictor of morbidity in adulthood: a systematic review and meta-analysis." Obes Rev **17(1): 56-67**



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Conclusions

- Current BMI centile cut-offs over-diagnose obesity in younger children
  - Raised fat levels are much less common at young compared to older ages
  - Young children with a high BMI centile have lower FMI than older children with the same BMI centile
  - Using current definitions, obesity in children under age 6 does not seem to be associated with later morbidity
- More stringent cut-offs are required for children under 6 years, matching the World Health Organization recommendation for 0-5 years
  - Overweight >2SD, Obesity >3SD
- We need to shift attention from early childhood to adolescents (and adults!)

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Bibliography

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- Wright, C. M., T. J. Cole, M. Fewtrell, J. E. Williams, S. Eaton and J. C. Wells (2021) Body composition data show that high body mass index centiles over-diagnose obesity in children aged under 6 years . Am J Clin Nutr. 10.1093/ajcn/nqab421
- Llewellyn A, Simmonds M, Owen CG, Woolacott N. Childhood obesity as a predictor of morbidity in adulthood: a systematic review and meta-analysis. Obesity reviews : an official journal of the International Association for the Study of Obesity 2016;17(1):56-67. doi: 10.1111/obr.12316.

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