Growth Monitoring in Pediatric Research

Katherine Morrison
Vanessa Ha
8July2016

Objectives

- Review anthropometric measures important in evaluating growth
- Review current best practices for anthropometric measurement in pediatric research
- Review the challenges with interpretation of anthropometric measures in children
- Discuss approaches to describing a trajectory

Measurement	Interpretation	Trajectory

KM Morrison
McMaster University

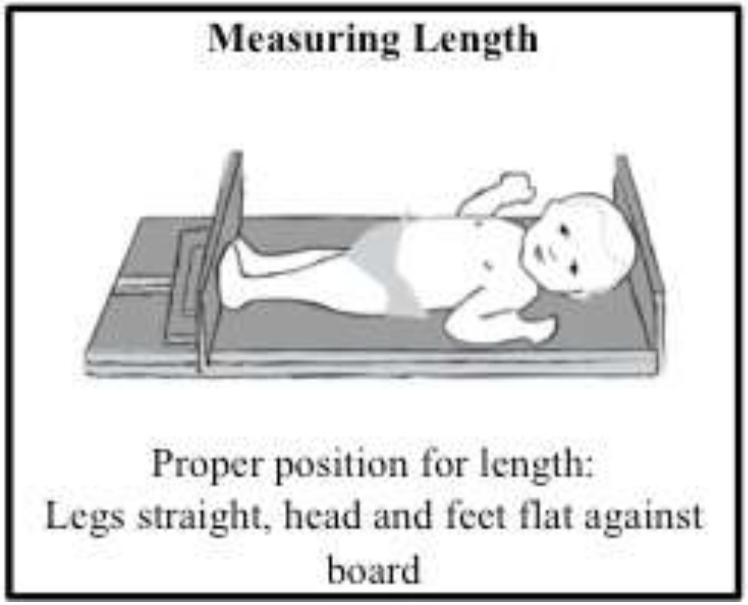
Anthropometry

Derived from the Greek – "Measure of Man"

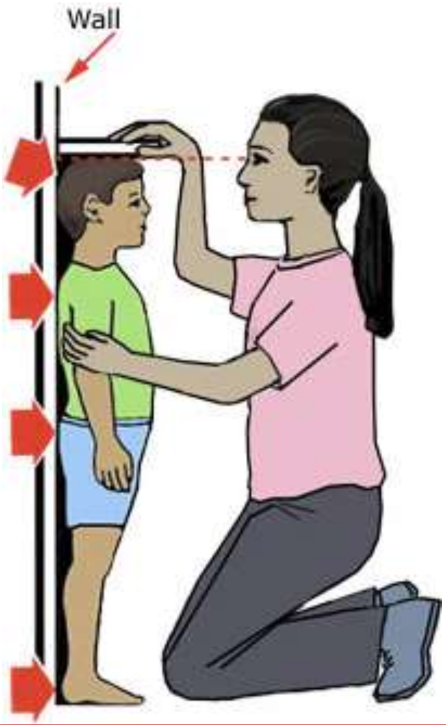
Measurement	Interpretation	Trajectory

Length & Height

Length



Height



When do you use height and when do you use length?

Weight

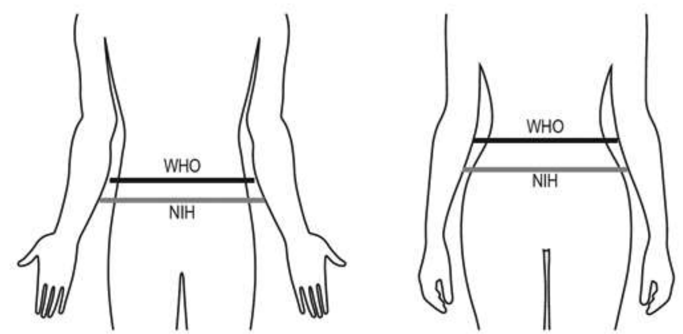
- Clothing and positioning are the only key items to monitor here
- The most accurately measured characteristic
- In the field for babies – can measure mother and subtract if no baby scale present….

Measurement	Interpretation	Trajectory

Waist circumference

- Lots of potential pitfalls!
  - Location
  - Clothing
  - Body positioning
  - Psychology????

Waist circumference measurement sites for men and women based on World Health Organization (WHO) and National Institutes of Health (NIH) protocols



Note: Following the WHO protocol, the measure is taken midway between the highest point of the iliac crest and the bottom of the ribcage. Following the NIH protocol, the measure is taken at the highest point of the iliac crest.

Waist circumference

Sex/Age group (years)	Difference									
	NIH measured versus WHO measured					NIH predicted versus NIH measured				
	≤1 cm	≤2 cm	≤3 cm	≤4 cm	> 4 cm	≤1 cm	≤2 cm	≤3 cm	≤4 cm	>4 cm
	%					%				
Boys	**53**	**81**	**92**	**98**	**2**	**69**	**93**	**97**	**99**	**1**
3 to 5	71	96	100	100	0	74	96	100	100	0
6 to 11	65	88	96	97	3	72	94	96	98	2
12 to 19	36	69	87	98	2	64	91	97	98	2
Girls	**34**	**58**	**75**	**85**	**15**	**53**	**80**	**92**	**95**	**5**
3 to 5	67	87	97	99	1	66	95	99	100	0
6 to 11	47	75	90	96	4	58	85	98	100	0
12 to 19	16	38	57	73	27	45	73	85	91	9
Men	**45**	**75**	**91**	**96**	**4**	**50**	**86**	**94**	**97**	**3**
20 to 39	41	73	91	98	2	53	87	97	99	1
40 to 59	47	76	93	96	4	47	88	95	97	3
60 to 79	49	78	90	95	5	53	79	90	95	5
Women	**25**	**48**	**67**	**81**	**19**	**38**	**71**	**89**	**96**	**4**
20 to 39	15	36	55	69	31	34	63	87	97	3
40 to 59	27	52	75	90	10	46	82	93	97	3
60 to 79	40	59	73	83	17	31	62	82	90	10

Note: Estimates are generated from sub-sample B.
Source: 2009 to 2011 Canadian Health Measures Survey.

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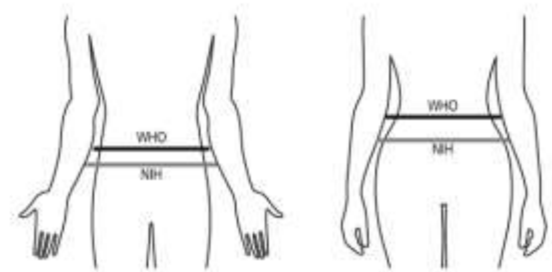

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Measurement | Interpretation | Trajectory

Body composition

FAT

- Interested in:
  - Amount
  - Location
  - Type?

LEAN MASS

- Most interested in
  - BONE
  - MUSCLE

FAT –estimated using skinfolds (amount/location), bioelectric impedance (amount - ?location), air displacement plethysmography (amount), DXA, MRI

LEAN MASS – estimated using midarm circumference, BIA, DXA

Measurement	Interpretation	Trajectory

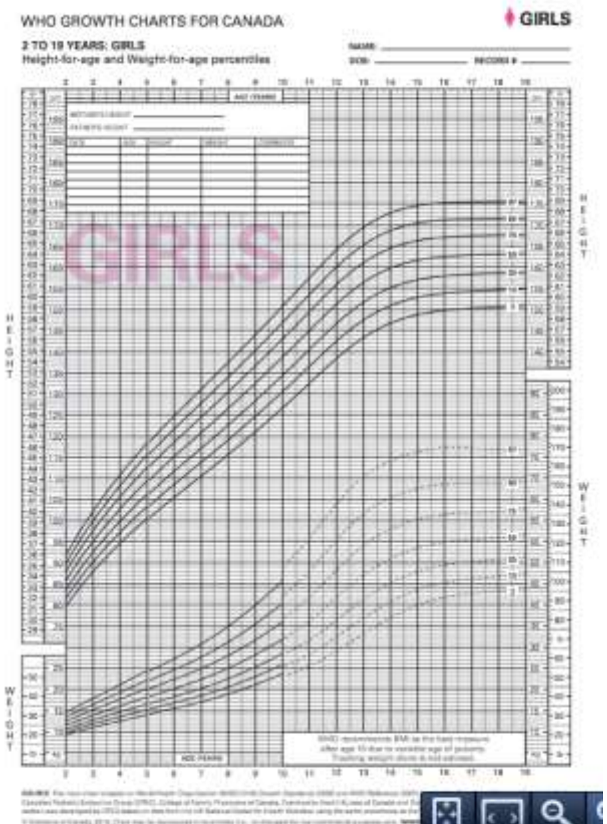
Interpretation

- What makes interpretation so challenging in the pediatric age group?

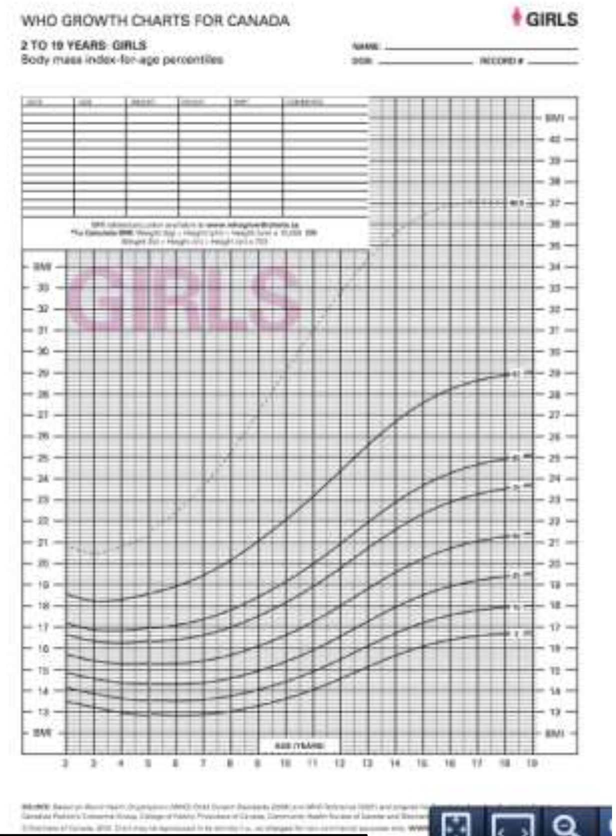
Measurement	Interpretation	Trajectory

WHO growth curves – Children and youth

Height/Weight for Age



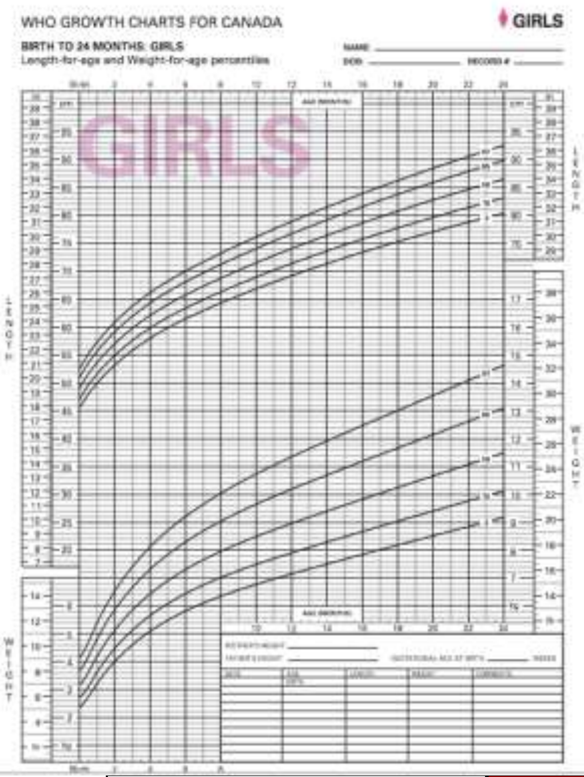
BMI for Age



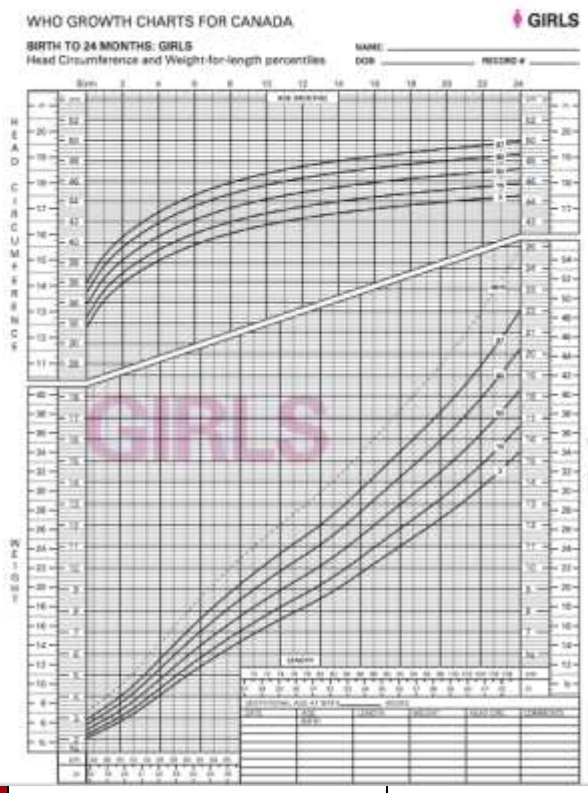
Measurement	Interpretation	Trajectory

WHO growth curves – Infants

Length /Weight for Age



Weight for length



Measurement	Interpretation	Trajectory

Which growth curves to use?

WHO Growth Standard

- Prospective longitudinal study to 5 years of age
- A growth standard as
  - Breast fed
  - Healthy
  - Multiple countries and ethnicities

CDC

- Historical – "pre obesity epidemic"
- Multiple sources
- Not based on longitudinal data capture
- No knowledge on health, many formula fed

Waist - growth charts (NHANES 1988-94)

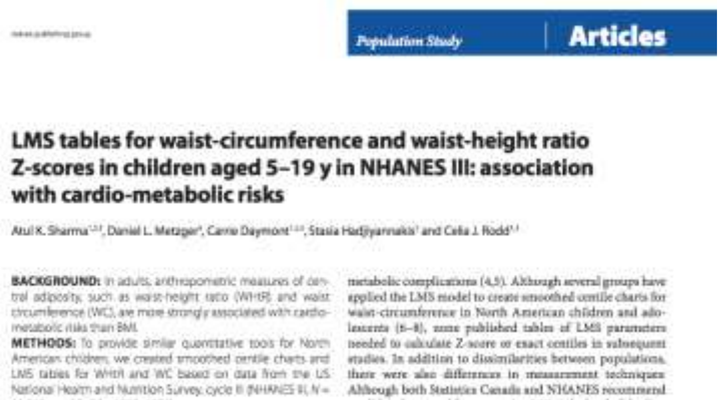
Waist

Waist for Height

http://cpeg-gcep.net/content/waist-circumference-and-waist-height-ratio-charts

Measurement	Interpretation	Trajectory

WC, W/HT, BMI


Population Study | Articles

LMS tables for waist-circumference and waist-height ratio Z-scores in children aged 5–19 y in NHANES III: association with cardio-metabolic risks

Atul K. Sharma, Daniel L. Metzger, Carrie Daymont, Stasia Hadjiyannakis and Celia J. Rodd

BACKGROUND: In adults, anthropometric measures of central adiposity, such as waist-height ratio (WHtR) and waist circumference (WC), are more strongly associated with cardio-metabolic risks than BMI.
METHODS: To provide similar quantitative tools for North American children, we created smoothed centile charts and LMS tables for WHtR and WC based on data from the US National Health and Nutrition Survey, cycle III (NHANES III, N =

metabolic complications (4,5). Although several groups have applied the LMS model to create smoothed centile charts for waist-circumference in North American children and adolescents (6–8), some published tables of LMS parameters needed to calculate Z-score or exact centiles in subsequent studies. In addition to dissimilarities between populations, there were also differences in measurement techniques. Although both Statistics Canada and NHANES recommend

Pediatric Research 78(6): 723, 2015

Table 3. Odds ratios (OR) and 95% confidence intervals for an adverse metabolic outcome corresponding to a unit increase in Z-scores

Outcome	Z-score	Odds ratio	95% CI
Total cholesterol	Waist-height	1.32*,‡	1.26–1.38
	BMI	1.18*,†	1.14–1.22
	Waist	1.25*	1.19–1.31
LDL cholesterol	Waist-height	1.38*,‡	1.27–1.51
	BMI	1.21*,†	1.14–1.29
	Waist	1.33*	1.21–1.45
HDL cholesterol	Waist-height	1.97*,‡	1.89–2.06
	BMI	1.53*,†,**	1.48–1.57
	Waist	2.03*,‡	1.94–2.13
Glycated hemoglobin	Waist-height	1.40*	1.14–1.74
	BMI	1.32*	1.14–1.52
	Waist	1.42*	1.13–1.78
Triglycerides	Waist-height	1.68*,‡	1.57–1.78
	BMI	1.36*,†,**	1.30–1.42
	Waist	1.61*,‡	1.51–1.71

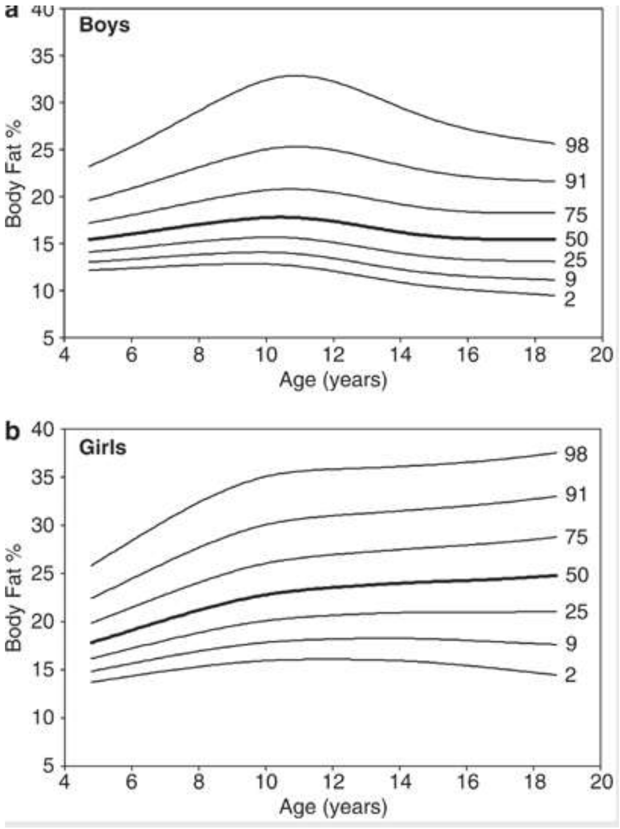
All ORs are significantly different from 1 (*$P < 0.0001$ vs. null hypothesis). Pairwise comparisons are marked by $^{\dagger}P < 0.05$ vs. OR for waist-height ratio Z, $^{\ddagger}P < 0.05$ vs. OR for BMI Z, **$P < 0.05$ vs. OR for waist circumference Z.

Measurement	Interpretation	Trajectory

Body fat curves

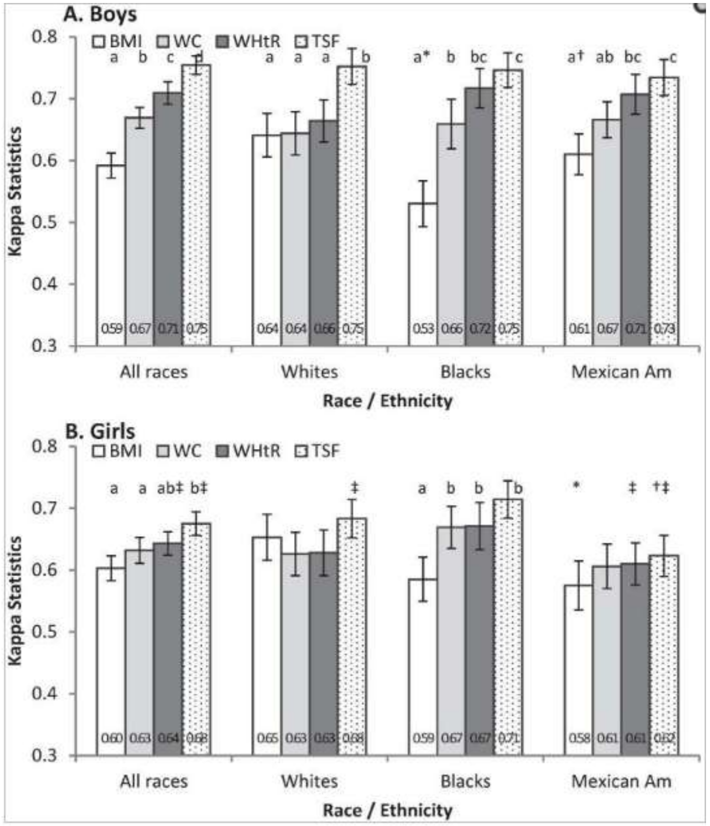
- Based on BIA
- Caucasian population in UK (n~2000)
- Measured in 1985

McArthy HD et al, IJO, 2006



Measurement | Interpretation | Trajectory

Which anthropometric measure best predicts body fat?



- N=5355 children age 8 – 19 y
- NHANES 2001-2004
- Compared quartiles of adiposity by BMI, WC, W/Ht and tricep skinfold to DXA

Nguyen TT et al, Obesity, 2014

Measurement | Interpretation | Trajectory

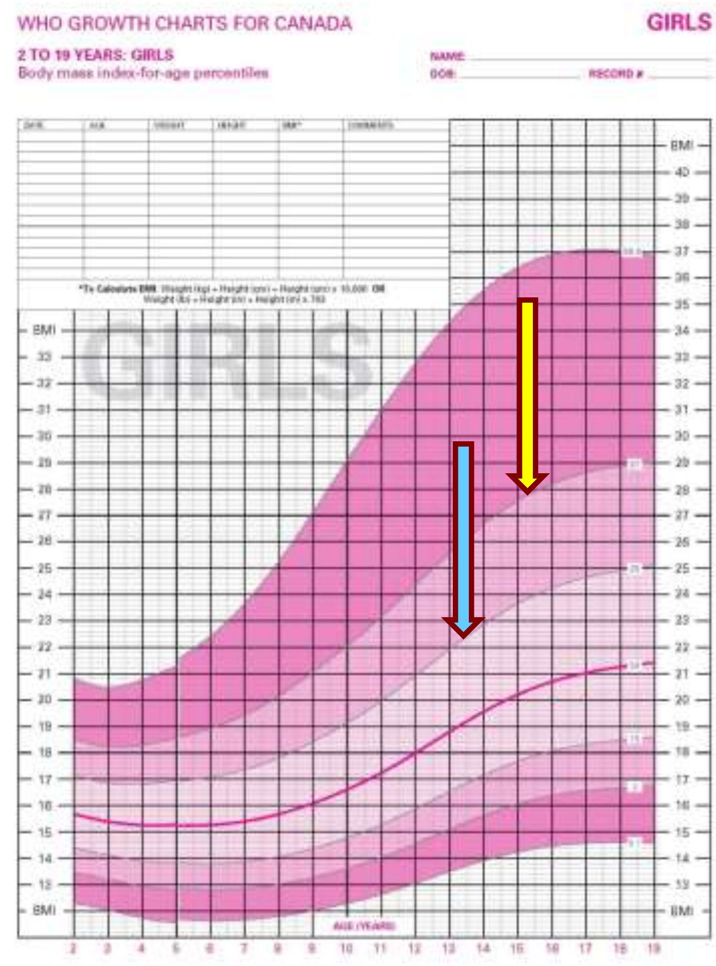
Growth in clinical research

Categorical vs continuous measure

Obesity classification in childhood: Clinical practice – WHO Curves

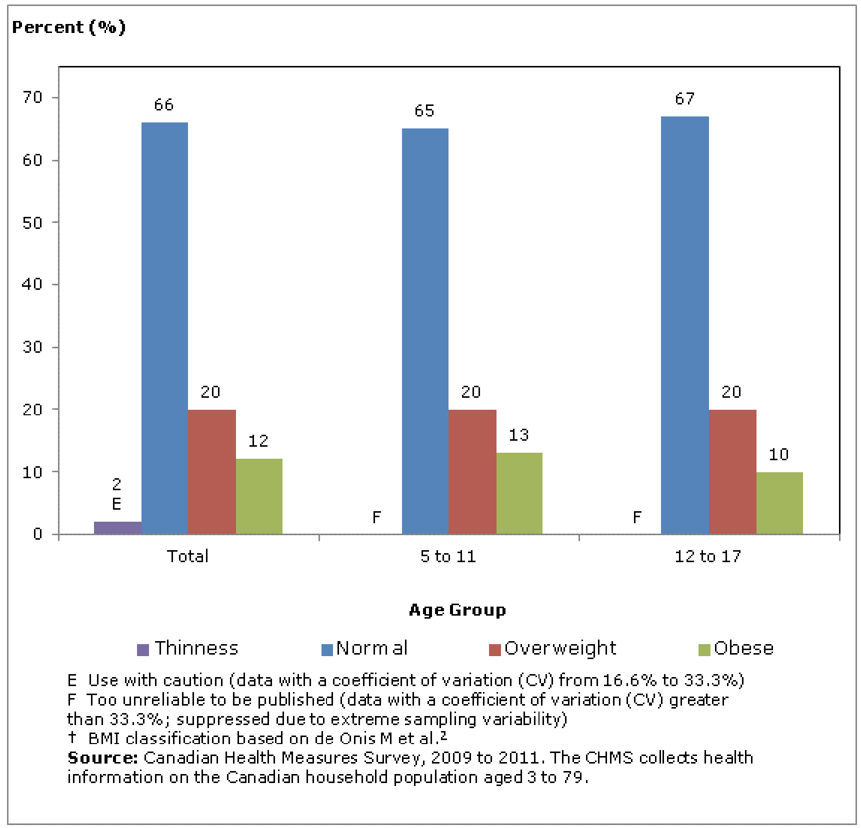
BMI

- Obesity: > 97th % or 2 SD for age and gender
- Overweight: >85th % or 1 SD for age and gender



Measurement	Interpretation	Trajectory

Prevalence of abnormal BMI – CHMS 2009-2011



Measurement | **Interpretation** | Trajectory

Classification of overweight & obesity – based on BMI

- WHO classification – suggest Z scores
  - Z scores are sex independent
  - Can use summary statistics
- CDC classification – 85th centile and 95th centile
- IOTF cut-offs (Cole, BMJ 2000) –
  - Based on ~200,000 individuals age 2-25. Curves linked to BMI of 25 and 30 at 18 years of age.

Classification of overweight & obesity – based on BMI

- WHO clas
  - Z score i ... s a fixed hei ... ten of the sam
  - Z scores
  - Can use
- CDC clas ... ntile
- IOTF cut-
  - Based on ... I of 25 and 30 at

Growth in clinical research

Categorical vs continuous measure

Measurement	Interpretation	Trajectory

Decisions to make

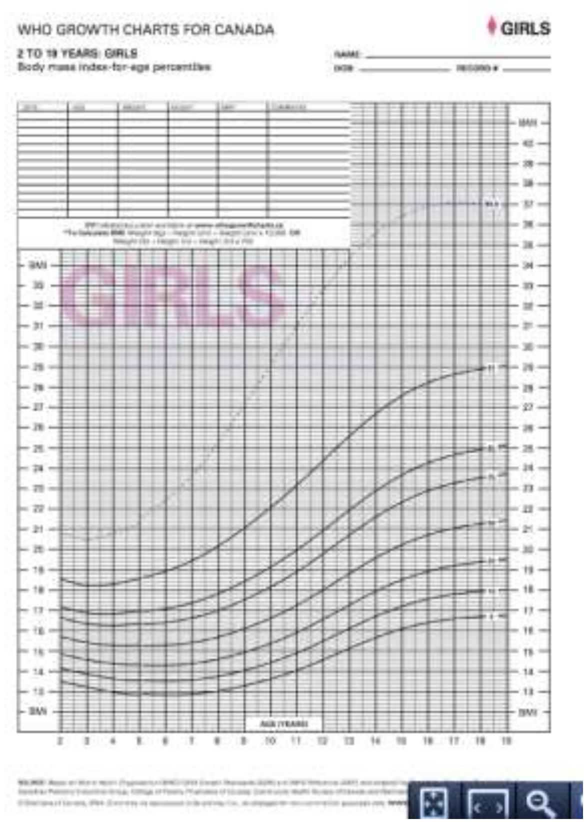
Decision 1

- What measure for adiposity
  - BMI / BMI z score
  - WC or W/Ht
  - Skinfold
  - BIA / BODPOD
  - DXA
  - Other?

How to analyze?

Measurement	Interpretation	Trajectory

WHO growth curves – BMI



SIMPLE METHODS

- Age at adiposity rebound
- Delta BMI Z score
- Delta BMI

MORE COMPLEX MODELLING

Measurement	Interpretation	Trajectory

INTERVENTION STUDIES - RCTS

European Journal of Clinical Nutrition (2005) 59, 419–425
© 2005 Nature Publishing Group All rights reserved 0954-3007/05 $30.00
www.nature.com/ejcn

ORIGINAL COMMUNICATION

What is the best measure of adiposity change in growing children: BMI, BMI %, BMI *z*-score or BMI centile?

TJ Cole[1], MS Faith[2], A Pietrobelli[3,4*] and M Heo[5]

- Based recommendation on BMI measure that had most consistent short term variability
- Principle: within-child short term variability should be same regardless of extent of adiposity
- Conclude BMI Z score best measure for single time-point
- BMI best measure for adiposity change

Measurement	Interpretation	Trajectory

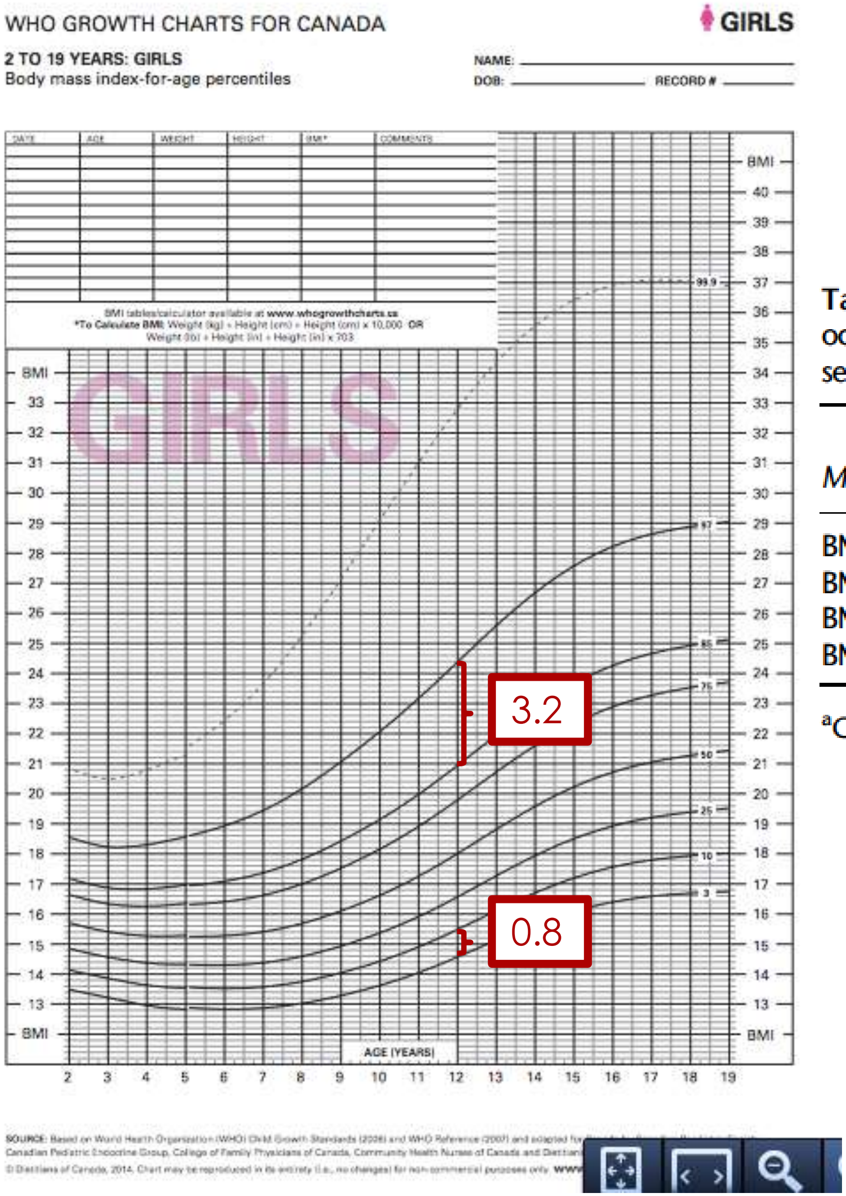


Table 2 Median (interquartile range) of the within-child s.d. across occasions for four measures of BMI change by obesity status, adjusted for sex and age

Measure	*Overall* (*N = 135*)	*Obese* (*N = 33*)	*Nonobese* (*N = 102*)	P-*value*[a]
BMI	0.39 (0.35)	0.42 (0.41)	0.38 (0.36)	0.2
BMI %	2.3 (2.3)	2.1 (1.7)	2.5 (2.4)	0.9
BMI *z*-score	0.29 (0.31)	0.20 (0.19)	0.34 (0.34)	0.004
BMI centile	6.5 (10)	2.3 (3.4)	8.9 (11)	<0.0001

[a]Calculated by two-sample *t*-test with square root transformation.

BMI% - % difference from median BMI
$=100 \log_e(\text{BMI}/\text{median BMI})$

Measurement | Interpretation | Trajectory

Growth models

- Latent growth curve modelling –
  - Repeated measures with known time between them
  - Relation of initial status and rate of change with time dependant (or time-independent) covariates
- Linear
- Non-linear
- Linear spline multilevel models
  - (Howe LD et al, Statistical methods in medical research, 2013)

Measurement	Interpretation	Trajectory

Examples / Discussion

Research Article

Trajectories of Change in Obesity among Tehranian Families: Multilevel Latent Growth Curve Modeling

Mahdi Akbarzadeh,[1] Abbas Moghimbeigi,[2] Hossein Mahjub,[3] Ali Reza Soltanian,[2] Maryam Daneshpour,[4] and Nathan Morris[5]

[1] *Department of Biostatistics, School of Public Health, Hamadan University of Medical Sciences, P.O. Box 65175-4171, Hamadan, Iran*
[2] *Modelling of Noncommunicable Disease Research Center, Department of Biostatistics, School of Public Health, Hamadan University of Medical Sciences, P.O. Box 65175-4171, Hamadan, Iran*
[3] *Research Center for Health Sciences and Department of Biostatistics, School of Public Health, Hamadan University of Medical Sciences, P.O. Box 65175-4171, Hamadan, Iran*
[4] *Cellular Molecular Endocrine Research Center, Research Institute for Endocrine Sciences, Shahid Beheshti University of Medical Sciences, P.O. Box 19395-4763, Tehran, Iran*
[5] *Department of Epidemiology and Biostatistics, Case Western Reserve University, Cleveland, OH, USA*

Citation: Nutrition and Diabetes (2013) 3, e60; doi:10.1038/nutd.2013.32

www.nature.com/nutd

ORIGINAL ARTICLE

Early life growth trajectories and future risk for overweight

JC Jones-Smith[1], LM Neufeld[2], B Laraia[3], U Ramakrishnan[4], A Garcia-Guerra[5] and LCH Fernald[6]

OBJECTIVE: Standard approaches have found that rapid growth during the first 2 years of life is a risk factor for overweight in later childhood. Our objective was to test whether growth velocity, independent of concurrent size, was associated with overweight using a nonlinear random-effects model that allows for enhanced specifications and estimations.
METHODS: Longitudinal data from a birth cohort in Mexico ($n = 586$) were used to estimate growth trajectories over 0–24 months for body mass index (BMI), length and weight using the SuperImposition by Translation and Rotation (SITAR) models. The SITAR models use a nonlinear random-effects model to estimate an average growth curve for BMI, length and weight and each participant's deviation from this curve on three dimensions—size, velocity and timing of peak velocity. We used logistic regression to estimate the association between overweight status at 7–9 years and size, velocity and timing of BMI, length and weight trajectories during 0–24 months. We tested whether any association between velocity and overweight varied by relative size during 0–24 months or birth weight.
RESULTS: SITAR models explained the majority of the variance in BMI (73%), height (86%) and weight (85%) between 0–24 months. When analyzed individually, relative BMI/length/weight (size) and BMI/length/weight velocity during 0–24 months were each associated with increased odds of overweight in late childhood. Associations for timing of peak velocity varied by anthropometric measure. However, in the mutually adjusted models, only relative BMI/length/weight (size) remained statistically significant. We found no evidence that any association between velocity and overweight varied by size during 0–24 months or birth weight.
CONCLUSIONS: After mutual adjustment, size during 0–24 months of life (as opposed to birth size), but not velocity or timing of

Measurement	Interpretation	Trajectory


Identifying obesity risk in the early years

Report on completion of a project funded by the Cross Government Obesity Unit

Hartwell House, Aylesbury, United Kingdom
July 2010

Darren Dahly, PhD
Mary Rudolf, MB BS BSc DCH FRCPCH FAAP
University of Leeds

Translational tools

Measurement	Interpretation	Trajectory

	Boys (3,090)	Girls (2,957)
Maternal obese only	**3.02 (1.95 to 4.66)**	**2.58 (1.67 to 4.00)**
Partner obese only	**2.70 (1.66 to 4.39)**	**2.50 (1.54 to 4.04)**
Both parents obese	**7.87 (4.48 to 13.52)**	**4.71 (2.52 to 8.80)**
Smokes*	1.32 (0.87 to 2.03)	1.34 (0.89 to 2.00)
Age		
<20	0.92 (0.32 to 2.60)	0.91 (0.28 to 2.99)
20-35 (ref)	1.0	1.0
≥35	**1.50 (1.01 to 2.22)**	0.97 (0.63 to 1.49)
Ethnicity		
White (ref)	1.0	1.0
Black	2.39 (0.89 to 6.41)	**3.74 (1.91 to 7.31)**
Asian	**2.63 (1.53 to 4,52)**	1.24 (0.66 to 2.35)
Other	1.72 (0.60 to 4.95)	0.98 (0.30 to 3.21)
Any Degree*	0.78 (0.51 to 1.22)	**0.55 (0.35 to 0.88)**
Gestational diabetes*	**2.86 (1.09 to 7.49)**	**3.99 (1.55 to 10.27)**
Wakes most nights*	**1.63 (1.15 to 2.31)**	1.03 (0.73 to 1.46)
Breastfeeding ≥3m*	0.90 (0.56 to 1.45)	1.01 (0.64 to 1.61)
HBW (>4kg)	**1.69 (1.12 to 2.56)**	**1.88 (1.18 to 2.98)**
Rapid early growth (>2 SDS)†	**2.49 (1.52 to 4.07)**	**2.93 (1.87 to 4.59)**

Estimates with 95% confidence intervals which exclude the null in **bold**.

* Dichotomised *Yes/No* variable, with *No* as the reference.

† Conditional weight gain, based on the updated 1990 British growth reference (Cole 1995)

- Millenium Cohort Study
- Obesity at 6 – 8 years (IOTF cut points for BMI

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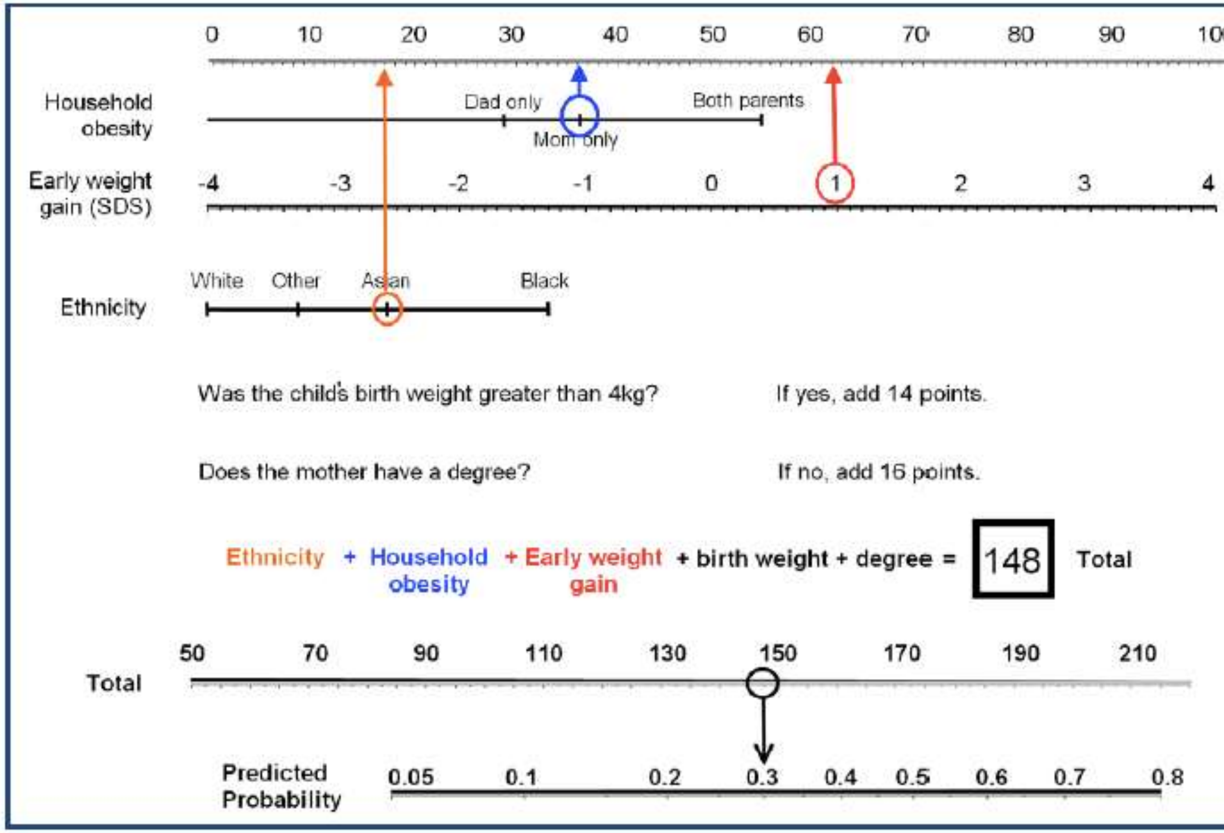

Figure 1. An example of how a paper version of an Obesity Risk Tool might look.

Points for the various risk factors are added up and the predicted probability read off from the scale at the bottom of the figure. For this high birth weight baby who is Asian with an uneducated obese mother who has shown weight gain in the normal range, the score would be 148 (38+62+18+14+16). The scale indicates a predicted probability of 0.29 – a roughly 1 in 3 chance of being obese at age 6 to 8 years

Measurement | Interpretation | Trajectory

Summary

- Growth is not simple
- Must consider:
  - Question
  - Feasibility of potential available methods
  - Utilize best practice to measure them
  - How best to analyze – this is likely the area that I see the greatest potential for development…