Anthropometric Measurements in Paediatrics - Do’s and Don’ts

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Anthropometry

‘Defined as the measurement of the human body’

‘....it is a simple reliable method for quantifying body size & proportions by measuring body weight, length, width, circumference, & skinfold thickness’

Assessment of Nutritional Status

1. First Line/Basic Assessment
   - Nutrient Intake
   - Clinical Assessment
   - Anthropometry

2. Second Line Tests
   - Biochemistry
   - Haematology

Image adapted from Shaw & Lawson (2007) Clinical Paediatric Dietetics
Importance of Anthropometry in Paediatrics
Body Weight

Informs the clinical picture =>
- Diagnosing (e.g. faltering growth in infants, NICE 2017; growth disorders)
- Monitoring growth/progress
- Nutritional status

Accurate measurement required when calculating:
- Macro/micro-nutrient requirements
- Medication/anaesthetic doses
- Fluid requirements
Height/Length

- Necessary for tracking growth & development in children
- Needed to calculate body mass index (BMI) - one of the most widely used screening tools to monitor nutritional status

Waist Circumference

- ...is a predictor of insulin resistance syndrome in children & adolescents – correlates highly with $^{\uparrow \text{ed}}$ metabolic risk factors for CVD & T2DM (Hirschler et al., 2005)
BMI (in > 2yr olds) – A useful measure of:

- Nutritional risk - & used in paed. screening tools (e.g. PYMS)
- Clinical/surgical risk e.g. complications post surgery
- Predictor of mortality & morbidity from chronic health issues related to being overweight/obese

- Used to define & diagnose childhood obesity/overweight
- Key parameter when monitoring the effects of dietary intervention
Anthropometry in Paediatrics - Do’s...

* For all anthropometric procedures – firstly, explain the process to the parent & child
Be Aware of …

- All the anthropometric measurements used in paediatrics
- Indications for using each measurement
- Limitations of each
- Practicalities in clinical practice
- Correct technique – formal training/accuracy
- Recommendations on how frequent to measure (healthy/sick)
- Equipment
- How to interpret data?
<table>
<thead>
<tr>
<th>Measurement</th>
<th>Derived Indices</th>
<th>Points to Note</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Body weight</strong></td>
<td>Weight for age</td>
<td>Easy to measure</td>
</tr>
<tr>
<td></td>
<td>Weight for age z-score</td>
<td>Use useful in everyday clinical practice</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Does not differentiate between lean tissue, body fat &amp; oedema</td>
</tr>
<tr>
<td><strong>Length/height</strong></td>
<td>Length/height for age</td>
<td>Difficult to accurately measure</td>
</tr>
<tr>
<td></td>
<td>Length/height z score</td>
<td>Needs more than one person to measure</td>
</tr>
<tr>
<td></td>
<td>Height age</td>
<td>Does not change rapidly</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Best overall indicator of nutritional wellbeing</td>
</tr>
<tr>
<td><strong>BMI</strong></td>
<td></td>
<td>BMI indicates relative weight for height, but does not differentiate between lean</td>
</tr>
<tr>
<td></td>
<td></td>
<td>and fat tissue</td>
</tr>
<tr>
<td><strong>Waist circumference</strong></td>
<td>Waist circumference for age</td>
<td>Easy to measure; requires removal of clothes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Distinguishes between high weight due to muscle bulk/fat</td>
</tr>
<tr>
<td><strong>Head circumference</strong></td>
<td>Head circumference for age</td>
<td>Easy to measure; useful up to the age of 2 yrs; useful as a proxy of length</td>
</tr>
<tr>
<td></td>
<td></td>
<td>increase; does not normally change rapidly; affected by medical condition;</td>
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<tr>
<td></td>
<td></td>
<td>may not indicate nutritional status</td>
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<tr>
<td><strong>Mid arm circumference</strong></td>
<td>Mid arm circumference for age</td>
<td>Easy to measure; useful to the age of 5 yrs; less likely to be affected</td>
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<tr>
<td></td>
<td></td>
<td>by water retention or fat deposition than body weight</td>
</tr>
<tr>
<td><strong>Skinfold thickness</strong></td>
<td>Tricept SFT for age</td>
<td>Difficult to measure accurately; unpleasant procedure for children;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>usually triceps are only used in children; distinguishes between lean</td>
</tr>
<tr>
<td></td>
<td></td>
<td>and fat tissue</td>
</tr>
</tbody>
</table>

Shaw & Lawson (2007)
Improving Accuracy – Minimising Error
(Daly et al., 1991)

- In assessing growth – accuracy is key
- Accuracy can be improved by minimising:

  **Instrument variation** – use of approp. equipment/calibrated

  **Subject variation** – take m’ments ≈ same time of day/similar conditions, & standardising methods/training

  **Observer variation** – errors ↓ by standardisation of methods/training
Body Weight
(1) Technique

Infants & toddlers (< 2yrs)
- Weigh nude ideally & without a nappy – scales placed on a hard surface
- Ideally - weight at the same time of day/consistently either before/after feed
- Record if weight was taken with/without a nappy

Children (> 2 yrs)
Ideally, should be weighed in vest & pants, but no shoes, footwear, dolls or teddies in hand
- For unsettled young children, consider taking parent’s weight 1st, then weigh both parent & child together – subtract parent’s weight from the total weight

Body Weight
(2) Equipment/Technique

Equipment/technique

- Scales should meet EC standards (Directive 90/384/EEC)
- Only Grade 3 clinical electronic scales in metric setting should be used – green sticker with background letter M (which means approved for medical use)
- Weigh in kg and g
- Calibrate & service equipment regularly
  - SECA recommend a service annually to ensure accurate readings
  
Body Weight
(3) Expected Weight Gain

In term infants, birth weight:
- doubles by 6 months
- triples by 1 year

<table>
<thead>
<tr>
<th>Expected Weight Gain</th>
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<tbody>
<tr>
<td>First 3 months</td>
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<tr>
<td>Second 3 months</td>
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<tr>
<td>Third 3 months</td>
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<tr>
<td>Fourth 3 months</td>
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<tr>
<td>1-2 years</td>
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<tr>
<td>Each year of age thereafter</td>
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<tr>
<td>until puberty</td>
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</tbody>
</table>

INDI Nutrition Support Reference Guide (2015); HSE
Assess Serial Measurements over Time

- Weight usually tracks within one centile
- A measurement pattern over time is what is most important
- Small dips – avoid focusing/being overly concerned about one-off dips
- Short period of wt. loss, followed by rapid catch-up, happens quite often if the baby has a viral illness/gastroenteritis/resp. infection
- Continuous weight loss is a cause of concern – needs r/v
- Referrals should be considered when there are ≥ 2 readings of concern with an appropriate time interval between m’ments (e.g. 2 wks if < 3mo)
Body Weight
(4) Frequency

In healthy term infants, weight measurements should be taken:
- At birth; then again at 6-8 weeks check with GP/Paediatrician or as needed
- At each PHN developmental check/opportunistic times e.g. immunisations
- School entry

In hospitalised sick infants:
- On admission
- Daily if there are issues with fluid balance/related concerns
- Otherwise, twice weekly weights is recommended (or alternate days)

NICE Guidelines on Faltering Growth (2017) - weekly from 1-6 months, fortnightly from 6-12 months, monthly from 1 year
Height/Length
1. Frequency

In healthy infants, length may be measured:
- At birth; the 72 hour visit by the PHN; 2 week check with the GP/practice nurse; 6 week check with GP/practice nurse
- At each PHN developmental check up to the age of 2 years

In sick infants, inpatients = measure weekly

In older children - if there are any concerns about growth/ wt. gain – consider more frequent measures

Height/Length
2. Equipment/Technique

For < 2 yrs
- Supine length is measured using a length board (infantometer) or baby mat
- Ideally – measuring length without a nappy or footwear
- Length measures for measuring preterm infants in incubators are available (Leicester Incubator Measure – measures up to 44cm)

For > 2 yrs or whenever a child can stand straight & unsupported
- Measure standing height using a stadiometer
- Good practice to take an average of 3 separate consecutive m’ments
- If a child is aged 2 yrs or older & cannot stand, measure supine length & subtract \(0.7\text{cm}\) to convert to height  (WHO 2008)
Measuring Length (< 2yrs)

Two people are required to measure length in infants - e.g. measurer & parent.

- Record to nearest 0.1cm.

When measuring length, tape measures are inaccurate & should not be used.
Measuring Height (> 2yrs)

- Ensure the Child is in the Correct Position
- Shoes must be removed
- Heels, bottom, back & head are touching the apparatus
- Eyes & ears at 90°
- Measure on the expiration
# Height/Length

## 3. Expected Longitudinal Growth

<table>
<thead>
<tr>
<th>Year</th>
<th>Growth Rate</th>
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<tbody>
<tr>
<td>1st year*</td>
<td>25cm/year</td>
</tr>
<tr>
<td>2nd year</td>
<td>12cm/year</td>
</tr>
<tr>
<td>3rd year +</td>
<td>6-10cm/year until growth spurt at puberty</td>
</tr>
</tbody>
</table>

*After the 1st month, approx. length increase of 2.5-3cm per month (HSE ([2018] ‘Your Child’s Growth, Weight and Length’))
4. Consider Calculating Mid-Parental Height...

- If the child’s ht. appears *disproportionate* to the adult ht’s of his/her biological parents
- Helps to assess if the child’s growth is proceeding as expected
- If either parent is not of normal stature – not appropriate to use
- Need to accurately check the ht. of both biological parents
5. Length/Height - Not Always Possible to Obtain

- Spinal deformity e.g. scoliosis, kyphosis; those unable to stand, CP
- Several proxy measures to monitor longitudinal growth

1. **Knee Height** – the preferred proxy measure of length/height as it has been shown to have the lowest level of technical error

   - Serial measurements of knee height may be useful to assess growth in those unable to stand (Hardy *et al.*, 2018)

2. **Upper Arm Length** - a reliable indicator to estimate stature in children aged 4-6.92yrs (Banik *et al.*, 2010)

3. **Lower Leg Length/Tibial Length**
Proxy Measure of Height

1. Knee Height

1. Measured with the child sitting down & the knee & ankle bent to 90°

2. On the left side, or least affected side, - using a sliding caliper – measure the distance between the heel to the superior surface of the knee over the femoral condyle

3. Two measurements should be taken & averaged

4. Doc. which limb the measurement was taken, & consistently use for subsequent measures
Knee Height (KH)
Estimate of Stature (S) in cm

- **Children up to 12yrs**
  \[ S = (2.69 \times KH) + 24.2 \]

- **White boys 6-18yrs**
  \[ S = (2.22 \times KH) + 40.54 \]

- **Black boys 6-18yrs**
  \[ S = (2.18 \times KH) + 39.60 \]

- **White girls 6-18yrs**
  \[ S = (2.15 \times KH) + 43.21 \]

- **Black girls 6-18yrs**
  \[ S = (2.02 \times KH) + 46.59 \]
Proxy measure of height
2. Upper Arm Length (UAL)

1. Face the child away from the measurer
2. Measure the right or least affected side
3. Bend the right arm at a $90^\circ$ angle at the elbow with the right palm facing up
4. UAL is measured posteriorly from the Acromion Process to the head of the radius (Olecranon Process)
   - Measure to the nearest 0.1cm & record
5. For accuracy, best to use an anthropometer (take average of 2 m’ments)
Upper Arm Length (UAL) Estimate of Stature (cm)

This measurement can be converted into a height measure & plotted on a normal growth chart, using the following formula:

$$\text{Stature} = (4.35 \times \text{UAL}) + 21.8$$

The technical error is +/- 1.7cm

(Samson-Fang & Bell [2013] Eur J Clin Nutr S5-S8)
Head Circumference (HC)
(or..Occipito-Frontal Circumference = OFC)

- HC is a simple, inexpensive & easily accessible tool for monitoring brain development & identifying infants at risk of neurodevelopmental disorders  (Garcia-Alix et al., 2004)

- HC usually tracks within one centile space (HSE, 2012)

- Frequency of measurement recommended at: (HSE, 2018):
  - ≈ the time of birth
  - 6 week check with GP
  - 3 month developmental assessment with PHN
**HC – How to Measure?**

1. HC is measured using a narrow, flexible, non-stretch plastic or disposable lasso tape
   *Do not use stretchy tape*

2. Measurement should be made just above the eyes to include the maximum circumference of the head, with the child supported in an upright position and looking straight ahead

3. Record measurement to the nearest 0.1cm; use average of 3 consecutive m’ments
Body Mass Index (BMI)
weight (kg)/height (m)² = kg/m²

- Simplest measure of thinness & fatness from age of 2 yrs (HSE, 2012)
- BMI is only meaningful when plotted correctly on age & sex specific centile charts
- BMI does not differentiate between well between heaviness due to lean tissue vs. excess fat deposition
- Should be interpreted with caution
- Waist circumference measurement is useful – a high BMI coupled with a high waist circumference will confirm fatness more conclusively
Small BMI Look-Up Chart
- no calculation required

Helps to detect if the child is falling into the overweight/obese range
BMI > 91\textsuperscript{st} centile = suggests overweight
BMI > 98\textsuperscript{th} centile = clinically obese

- BMI < 2\textsuperscript{nd} centile = can detect undernutrition
For More Accurate Assessment of BMI

New BMI Charts (2-20yrs) based on WHO data & UK 1990 (4-20 year) data

UK (1990) BMI Charts
- 6 months-20 years
Waist Circumference (WC) - a useful tool to identify central obesity

- An indirect measure of central adiposity
- Easy, simple measure with inexpensive equipment
- Has a low observer error, offers good reliability & validity\(^1\)
- Can help distinguish between a ↑ weight for age that is caused by ↑ body lean tissue or ↑ body fat

SHORT COMMUNICATION

What is the best way to measure waist circumference?

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Abstract
Waist circumference is a measure of potential value in paediatrics, given its relation to cardiovascular risk in adults. However, three different methods of measurement are currently in use, giving potential for confusion. This study was undertaken to assess consistency across the measures in a population of overweight and normal weight children. We found that when expressed as standard deviation score (SDS) on the British 1990 reference, all three methods correlated highly with body mass index standard deviation score (BMI SDS); however, there was bias and variability between the measures. Based on ease of measurement, the site 4 cm above the umbilicus was the most convenient. This method was also endorsed by children’s views. We therefore recommend that 4 cm above the umbilicus is adopted for clinical use until such time as the methods are verified against the gold standard of visceral fat, as measured by magnetic resonance imaging scan.

Key words: Waist circumference, abdominal girth, waist measurement

Introduction  undertook a study to assess the consistency be-
How to Measure Waist Circumference?

The waist is defined as the mid-way point between the lowest rib cage & the iliac crest – & should be measured preferably with a special tension tape.
Any Anthropometric tape used should be:

- Flexible
- Non-extensible
- Metal tapes are preferable to plastic-coated fabric tapes, which can stretch with use over time (↑ing measurement error risk)
- Ideally should be narrow & have a blank space at the beginning of the tape
- Clean with a disinfectant wipe, you must dry the length of the tape with a hand tissue before allowing the tape to retract

E.g. Lufkin Executive Thinline Tapes
- 2 meters; code: W606PM
- Can buy on Amazon
How to Measure WC?

- Child wears only underclothes ideally; feet together
- Weight evenly distributed with arms relaxed
- Breathing normally - take the waist measurement at the end of a normal expiration
- If wearing a shirt or vest, deduct 1cm before recording & plotting the measurement
- Before reading the tape measure, ensure that it is snug but does not compress the skin, & is parallel to the floor
- Measure to the nearest 0.1cm (1mm); take an average of 3 m’ments
UK90 BMI Identification Chart

Harlow Printing


- £30 for 100 charts
Growth Charts
Do’s and Don’ts......
https://www.hse.ie/eng/health/child/growthmonitoring/#charts
Growth Charts
Do’s…. 

- Accurately plot weight & height/length on appropriate age & gender-specific growth charts
- Know what growth chart to use
- & the growth charts recommended by the HSE (2012) by age group
- Term infants (≥ 37 wks) – use UK-WHO 0-4 yrs

- Preterm infants 32-36 weeks gestation –
  - plot in ‘Preterm Section’ of the UK-WHO 0-4 years chart, until 42 weeks gestation

- Use the Neonatal & Infant Close Monitoring (NICM) LBW chart
  - For infants < 32 weeks
  - For any (sick) neonate needing close monitoring
  - After 2 years corrected age, UK-WHO 0-4 years charts can be used
For Children > 4 years:

- New growth charts will be constructed based on data-generated centiles derived from Irish reference data of the 1980s (Hoey H, Tanner J & Cox L, 1987) to merge with younger child charts.

- 'As an interim measure until these new charts are available, the UK growth charts 2-18yrs will be used to assess growth in children over 4 years up to 18 years old.'

- For now, in > 4 year olds - use UK-WHO 2-18 year old charts.
Growth Charts & Plotting

Check if time increments are in months, weeks, or decimal age

- Plot all term infants (37 or more weeks) at term (age 0)
- Infants born < 37 wks gestation are ‘preterm’
- Only correct for gestational age in preterm infants (not term)
- For infants born 32-36 weeks – correct to 1 year of age
- For infants born before 32 weeks, correct to 2 years of age
- Corrected age: chronological age minus the number of weeks born before 40 wks of gestation
- For consistency & to standardise practice – get team agreement
Where to Access Growth Charts?

- Available to order from Harlow Printing
- ≈ £23 for 100 growth charts
  
  https://www.rcpch.ac.uk/resources/growth-charts

- Specific growth charts: Down’s Syndrome, Turner Syndrome, Williams Syndrome
UK-WHO Neonatal Infant Close Monitoring Growth Chart

Designed for plotting growth measurements of preterm +/- LBW infants from birth-2 yrs, after which the UK-WHO 0-4yr charts can be used.
This growth chart combines WHO standards with UK preterm & birth data. The charts depict a healthy pattern of growth that is desirable for all children, whether breast fed or formula fed, & whatever ethnic origin.
Chart designed to assess the growth of school age children and young people.

The growth of most children < 4 years of age should be plotted on the more detailed UK-WHO 0-4 year growth charts.
Growth Charts

...Don’ts

- Inaccuracies in growth plotting - particularly affect infants/prems

- Measurements should be plotted on the relevant centile chart using a **small dot** rather than a cross or circle – or joined dots

  - If infants are regularly monitored/measured, several circled dots makes it difficult to plot & interpret patterns

- When > 1 health professional monitors an infant – it can get confusing when measurements are plotted using both uncorr. & corrected age

  - Lack of adjustment - ↑es risk that the child is classified as faltering growth

  - Consider team agreement to only plot measurements using corrected age
Is weight gain due to lean & fat tissue, or merely fat?

Increases in Mid Upper Arm Circumference (MUAC) are more likely to comprise of muscle and less likely to be affected by oedema than body weight

- MUAC indirectly assesses nutritional status by est. body fat & muscle bulk
- In < 5 year olds, MUAC is a useful tool to identify malnutrition
- Highly correlated with BMI
- Non-invasive, inexpensive, easy to measure, requires minimal training
- Less affected by acute dehydration than weight-based indices
MUAC - How to Measure (1)?

**Step 1.** Identify the mid-point between the shoulder (acromion) & elbow (olecranon)

- Patients non-dominant arm should be bent at the elbow at a right angle (90°) with palm up
- Measurement should be done on the posterior surface of the arm
- Using a tape measure, measure the distance between the acromion (bony protrusion surface of upper shoulder) & the olecranon process (bony point of elbow)
- Whilst still holding the tape in place, make a short horizontal line at the mid-point
- This marks the level at which the circumference will be measured

Mark the mid-point with a pen
Step 2. Measure the MUAC

- Patient should stand with non-dominant arm hanging loosely by their side; supine position fine too
- Important that the child’s arm is relaxed as a tense arm will give a very different reading
- Align the tape around the upper arm such that the mid-point mark is situated between the two parts of the tape
- The tape should be snug around the arm horizontally – do not cause pinching or indentation
- Take the average of 3 MUAC m’ments

Interpreting MUAC Measurement

- Standards for MUAC are age & gender dependent
- References available from the National Health and Nutrition Examination Survey (USA-data from 3-5 months up to 19 yrs)
- In children < 5yrs, a MUAC < 14cm is likely to indicate sig. malnutrition

| Mid Upper Arm Circumference of 1-5 year olds (Hobbs et al., (1999)) |
|--------------------------------|---------------------------------|
| < 14cm                         | Very likely to be a significantly malnourished child |
| 14-15cm                        | May be malnourished               |
| > 15cm                         | Nutrition likely to be reasonable |
Be Aware of Recognised Growth Patterns in Specific Paediatric Populations
(1) Term Infants
- be familiar with recognised infant growth patterns

- 50\textsuperscript{th} centile birthweight for infants \(\approx 3.5\)kg

- Growth patterns \textbf{over time} are more important than isolated m’ments

- Breastfed vs. formula fed infants – differ in growth pattern

- From 2 months-1 year formula-fed infants gain weight & length more rapidly than breast-fed infants (Zeigler \textit{et al.}, 2006)

<table>
<thead>
<tr>
<th></th>
<th>Breastfed</th>
<th>Formula fed</th>
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<tbody>
<tr>
<td>0-6 months</td>
<td>More rapid growth</td>
<td>Slower growth</td>
</tr>
<tr>
<td>6-12 months</td>
<td>Slower growth</td>
<td>More rapid growth</td>
</tr>
</tbody>
</table>

HSE Unit 6 ‘Growth Monitoring’ (2012)
Infants – Early Weight Pattern

- Some weight loss first 5-7 days is expected & normal
- Birth weight is usually regained by the 10th-14th day of life
- Loss of 10% of birth weight by 2 wks needs further r/v
- The child’s max. weight centile achieved between 4-8 wks may be a better predictor of the centile at 12 months, than the birth centile (Edwards et al., 1990)

Some degree of weight loss is common after birth. Calculating the percentage weight loss is a useful way to identify babies who need assessment.
(2) Preterm Infants

- Fat content of premature infants is 8% (DEXA)

- & up to 25% at term infants (Fusch et al., 1999)

- Fat mass is continuously accumulated during the third trimester of intrauterine development, & the water content of lean body mass drops – hence reason for the $\downarrow^{\text{ed}}$ fat content in prems

- In VLBW infants - Intrauterine growth retardation is an independent risk factor for poor growth during the first year (Tsang et al., 2005)
3. Other Paediatric Populations
1. Spinal Deformity – Adolescents with Scoliosis
- Irish data - sig. lower weight & BMI compared with healthy controls
- Systematic r/v - sig. ↓er BMI than controls (Tarrant et al., 2015; 2018)

2. Food Allergy
- Poor growth related to avoidance diet; lower weight, weight for length & BMI vs. controls
- Children avoiding all forms of milk are shorter & weigh less than matched counterparts
- The presence of a milk and/or soy allergy impacts linear growth (Rhodes et al., 2016; Hobbs et al., 2015; Mehta et al., 2014)

3. Ketogenic - Rapid ↓ in weight z scores in the 1st 3 months; ↓ in height z scores in the first 6 months (Vining et al., 2002)
Anthropometric Measurements

Limitations to their Use & Accuracy in Clinical Practice
Limitations in Clinical Practice

- Accurate plotting & recording
- Severity of Disease/ICU/spinal deformity – difficulty measuring
- Practicality at ward/OPD level e.g. time, resources, unsettled child
- Lack of necessary equipment / calibration
- Variance in inter-observer technique/practice
- Oedema/issues with fluid balance
✓ In assessing growth, **accurate anthropometric measurements** is a key consideration

✓ Accurate anthropometry relies on **appropriate technique & instrumentation** by a trained clinician

✓ Relevant growth charts & precise plotting – team agreement to standardise this

✓ Serial measurements showing **a pattern over time** is most important

✓ Be familiar with **recognised growth patterns** in paed. population in your area

✓ Abnormal growth patterns will allow **early intervention** before poor patterns of nutrition & growth become established
Key References

   https://www.hse.ie/eng/health/child/growthmonitoring/
   - video demos
   - practice activities
   - HSE Land: modules on ‘National Healthy Childhood Training Programme - Welcome and Introduction’ & ‘Growth Monitoring in Children’

   - Paediatric Section

   ‘A Training Course on Child Growth Assessment’


If you wish to become a ‘Certified Anthropometrist’ (Level 1-3)...

- Dedicated to formal training in Anthropometry
- Training applicable to paediatrics
- The International Society for the Advancement of Kinanthropometry (ISAK)
- ISAK has developed an international anthropometry accreditation scheme
- For details on courses in Ireland: https://www.isak.global/WhatIsIsak/Index