OPEN ACCESS
Freely Available Online

INTERNATIONAL JOURNAL OF NUTRITION
ISSN NO: 2379-7835

Review

DOI: 10.14302/issn.2379-7835.ijn-19-3111

Evolution of Anthropometry in Malnutrition

M. Phadke[1,*], R. Nair[2], P. Menon[3], V.Singal[4]

[1]Sr.Adv, Public Health, Govt. of Mah, UNICEF, Mumbai, India

[2]Nutrition Specialist, UNICEF Maharashtra, Mumbai, India

[3]Assoc. Prof., GIBN, Mah. Uni. of Health Sci., Aundh, Pune, India

[4]Secretary, DWCD, DG Nutrition Mission, Govt. of Mah., Mumbai, India

Abstract

The present paper describes the significance of anthropometric measurements in detecting nutritional status of individuals, specially children. It highlights evolution of anthropometry, discusses importance of various measurements & their role in determining undernutrition & obesity. There is a need to have one measurement to detect obesity & undernutrition both. An ideal such measure is yet to be established.

Corresponding author: Mrudula Phadke, Sr. Adv, Public Health, Govt. of Mah, UNICEF, Mumbai, India. Email: drmapaa@yahoo.com

Keywords: Anthropometry, obesity, malnutrition

Received: Nov 28, 2019 **Accepted:** Dec 30, 2019 **Published:** Jan 01, 2020

Editor: Natalia UrzÃºa, Doctor of Biological Science Postdoctoral veterinary pharmacology National University of Rio Cuarto.

Background

Assessment of nutritional status of a child is necessary for early detection of malnutrition for long term recovery, prognosis, response to treatment, for assessing effectiveness of preventive programme and finally to detect & extrapolate it on both ends of the spectrum of malnutrition i.e. undernutrition and obesity. The present article deals with a review of various methods to detect malnutrition and the way forward.

Methods to Detect Malnutrition

Various methods are used to detect malnutrition viz. those based on clinical examination, those based on measurement of dietary intake (including breastfeeding, complementary feeding), biochemical methods and anthropometry.

Clinical assessment can easily detect severe forms of malnutrition with obvious signs like visible wasting, oedema, skin changes, hair changes, growth retardation, apathy, mental changes, hepatomegaly etc. Clinical examination involves a lot of subjectivity. Therefore, its specificity and sensitivity is high only in severe forms of malnutrition and diagnosis depends on the astuteness of the clinician.

Detection of malnutrition by biochemical tests involves simple tests like serum albumin or complex ones like serum & urinary creatinine, urea & their ratios. These investigations are time consuming, invasive & yield results with low sensitivity or specificity. They cannot be tried in field settings.

Dietary recall by the parent or caregiver along with weighing the child before and after feeds has also been used in addition to clinical examination to get an idea about malnutrition. Obviously, its success depends on educational status and intelligence of the mother and the time she devotes for the baby. Dietary component in the procedure is also to be combined with history of diarrhea, malabsorption in a given case to determine the degree of malnutrition. All these tests have their own merits & demerits.

Anthropometry has always been an important and the best tool in the diagnosis, management & prognosis of malnutrition in clinic and in community settings. The science of body measurements in children & adults has evolved over the last century. The present paper deals with the development of anthropometry over years and those anthropometric measurements which should form the basis of diagnosis, prognosis & recovery in malnutrition.

Methods

Various Anthropometric Measurements Help to Assess Malnutrition. They are as under :

A) Age dependant anthropometric measurements **-**

1) Weight (Wt)
2) Height (Ht)
3) Occipitofrontal circumference (Head circumference)
4) Chest circumference
5) Wt for age, Ht for age

B) Age independent (or partially dependent) anthropometric measurements -

1) Mid upper arm circumference (MUAC)
2) Body mass index (BMI)
3) Skin fold thickness – triceps, subscapular,biceps,suprailiac etc.
4) Indices – Wt. for height, Wt for length
5) Various ratios

Weight & Height

Taking weight and height of a child or weight and length of an infant is relatively easy and inexpensive in a clinic setting.It does not need complicated instruments or extensive training of personnel. When combined with age, it gives good indication of the nutritional status of the child. Nearly two decades ago, growth monitoring was done mainly on the basis of wt. for age of the child. Weight gain or weight faltering or even weight loss for age gave an idea about the growth of the baby for that age. This was measured in terms of the percentage of the median of Harvard growth standards. Thus the measure would be in terms of median wt for that age. So, grade-I malnutrition was weight of 71-80% of median, grade-II 61-70%, grade-III 51-60% & grade-IV was below 50% of the median. However, with the development of World Health Organization (WHO) growth charts in 2006 and expressing weight in terms of percentiles, it was seen as a better index to reflect nutritional status in terms of SD or Z-score. Thus, expression of weight for age gave an idea whether the child was normal, moderate underweight (MUW) as <-2SD or severe underweight (SUW) as <-3SD. This classification deals with the chronic nature of weight faltering, it is a composite index and is age dependent. It can broadly categorize children at risk.

However, a better index is a measure of wt. for height of the child, using percentile WHO growth charts[1].By using this method, children are classified as ' normal, or with moderate acute malnutrition (MAM) <-2SD or with severe acute malnutrition (SAM) or wasting <-3SD'. This is a measure of acute weight loss and identifies children at a high risk of dying (9 to 20 times increased risk as against wt. for age where in the risk is around 4 times more). Weight for ht. is an age independent index, is used to detect acuteness of the illness and often used now to categorise malnutrition (WHO).

A clinical analogy for difference between wt. for age & wt. for height measure would be the one of lipid profile and ECG with cardiac enzymes in an old person. Lipid profile may identify individuals at a chronic risk of coronary artery disease but ECG and cardiac enzymes are pointers towards acuteness of the coronary artery disease and myocardial infarction. Therefore, in clinical settings now, detection of undernutrition should be done by weight for height.

The third index used is height for age which detects if a child is stunted for age. This is again an age dependent index like the first index and gives an idea about chronicity of nutritional deprivation. All these indices (underweight, wasting & stunting) are used in clinical practice to get an idea about nutritional status of the child, but wasting is the best index to be used to identify children who are at high risk of death and who need to be treated immediately. (Table 1)

MUAC-(Mid upper arm circumference).-It involves measuring the circumference of the mid upper arm region of the child. It is done by using a measuring tape encircling the mid upper arm region of the child at the level which is midpoint between acromion and olecranon.MUAC of less than 11.5 cm in children between 6 months to 5 years indicates severe malnutrition, between 11.5 to 12.5 cms indicates moderate malnutrition and that above 12.5 cm indicates a normal child. It is a rough measure , is easy to perform and is generally used in emergency settings in the field. It has limited sensitivity.

Various ratios related to height, weight and midarm circumference – Many scientists have devised ratios that may make the results more sensitive and specific.

These are enumerated below:

a) QUAC stick (Quaker Arnold MAC) (Quaker arm circumference measuring stick).

Mid arm circumference for height. A child taller for his arm circumference for height is malnourished (Normal – 75 to 85%).

b) Kanawati and McLaren's index- MUAC in cm 0.32-0.33 is normal. <0.25 is SAM
Head circumference in cm.

c) Kanawati Index – Ratio of MUAC and head circumference. It varies between 0.32 – 0.33. A ratio of less than 0.25 indicates SAM.

d) Rao's ratio = $\dfrac{\text{Wt in gms}}{\text{height in cm}^2} \times 100$

* Normal is 0.0015.
* Value between 0.0013-0.0015 is moderate malnutrition and below 0.0013 is SAM.

e) Rao and Singh's index = $\dfrac{\text{Wt in kg}}{\text{height}^2 \text{ in cm} \times 100}$

* 0.14 normal.
* 0.12 – 0.14 malnutrition.

f) Dugdale's index = $\dfrac{\text{Wt in kg.}}{\text{height}^{1.6} \text{ in cm}}$

* 0.88 – 0.97 normal
* Below 0.79 is malnutrition.

g) Jelliffe's ratio – Head circumference/ chest circumference

* Ratio above 1 in a child more than 1 year is malnutrition.

h) Quetelet index = $\dfrac{\text{Wt in kg.}}{\text{height in cm}^2}$

i) Ponderal index = $\dfrac{\text{Wt in gms.}}{\text{Length in cm}^3} \times 1000$

Table 1. gives details about Wt. for age, Wt. for ht and Ht. for age

1) Wt. for Age	2) Wt. for height	3) Ht. for age
a) Composite Index. Detects Acute & Chronic malnutrition. Underweight - Moderate underwt MUW, Severe underwt SUW	a) One index. Detects Acute malnutrition. Wasting - Moderate acute Malnutrition (MAM), Severe acute malnutrition (SAM).	a) One index. Detects chronic malnutrition - Stunting. Moderate stunting, Severe stunting,
b) It gives an indication of how the baby is growing.	b) It gives information about baby's wt. during past 3 weeks (As ht. does not change much in 3 wks).	b) It gives an indication of height of the baby for its age.
c) It is a Screening test (sensitive)	c) It is a Specific test	c) Stunting is indicative of chronic nutritional deprivation but good adaptation by body.
d) Similae- S. Lipids & Cholesterol Predict risk of Heart Attack	d) It is like ECG- Specific. Gives indication if the Patient has a heart attack	d) --
e) Age dependent - Age may not be stated precisely by uneducated parents or caregivers. Then it can give incorrect results.	e) Age independent - However, it can be affected by dehydration.	e) Age dependent
f) Easy to measure; Less training required. Accredited Social Health Activist (ASHA), Anganwadi Worker (AWW) can use it in the community."	f) More training required. Auxiliary nurse midwife (ANM), Supervisor, Doctors can use it.	f) Training required. Doctors & Supervisors can use it.

* Index less than 2 means asymmetric intrauterine growth retardation(IUGR)
* 2 – 2.5 borderline malnutrition & more than 2.5 is appropriate for
* for gestational age (symmetric IUGR)
* Ponderal index is also called as Rohrer index or corpulence index

j) BMI –This is now the most commonly used index..It is used to detect obesity. Obesity has been defined by using BMI (body mass index – wt in kg/height in meter^2) in adults.. n recent years, the need to measure childhood obesity is increasing rapidly, considering the emerging epidemic of obesity & syndrome X (Hyperlipidemia, diabetes, hypertensioin, coronary artery disease), especially in low and middle income countries (LMICS). BMI between 18.5 – 24.9 is normal, 25-25.9 is overwt, above 30 is obesity, 15-18.5 is underwt, 13-14.9 is moderate underwt & below 13 is severe underwt.

Obesity in Children

Various growth charts using Z-scores are being used for children. Those with weight more than +2 Z-score or +2 SD on growth charts are considered to be obese. There has been varied opinion on the use of WHO growth charts for obesity. Use of these charts with cutoffs for under-5 years is likely to misclassify children as obese[2]. Children above 5 years are classified as obese with >1 SD BMI by some scientists. BMI cutoffs are still not considered as ideal for detecting obesity[3]. So, one is in a dilemma as to which one measurement is to be used to measure wasting and obesity both i.e. the wt for ht or BMI charts.

Timeline of Events in Anthropometric Measurement

At This Juncture it may be Pertinent to Note the Evolution of Various Anthropometric Markers. (Table 2)

1. Quetelet Index - This is a body mass index which is Wt/stature^2 . It was first described by Adolphe Quetelet in 1832. It allowed comparison of weights between adults with varying heights. He used it to detect obesity.

2. Rohrer Index – In 1921, Rohrer introduced the Ponderal index which is Wt/stature^3. With 'stature cubed' an adjustment is made appropriately for height because of different dimensions of infants. (Body proportions of an infant - Upper segment : Lower segment 1.6:1). This is done so that weights of infants with different lengths could be directly compared. Ponderal index was used as a measure of asymmetric intrauterine growth retardation in a newborn.

At this juncture, though it was agreed that Quetelet BMI was useful in adults and Ponderal index was useful in infants, what measure to be used for children and adolescents was not defined[3].

3. Dugdale – Dugdale in 1971 showed that Wt/ht$^{1.6}$ is a better index of malnutrition.

4. Keys – In 1974, Keys reported Quetelet's BMI to be the best proxy for body fat percentage in adults.

5. Roche : In 1981, Roche compared BMI to the Ponderal index & skinfold thickness to total body fat in individuals from 6 to 49 years. They noted that wt/stature^2 was an indicator of total fat in girls while sub-scapular skinfold thickness was better for boys.

6. Michielutte – In 1984, Michielutte found that Quetelet's BMI was better correlated with triceps skinfold thickness than Rohrer's Ponderal index among 5 to 12 year old children in North Carolina. This can be better understood when one considers that the upper segment : lower segment ratio in 5 to 12 year old changes from 1:4 to 1:1 i.e. adult proportions.

7. Burton – In 1985, Burton proposed that 85th centile of BMI was an indicator of overwt. in adults.

8. Must – In 1991, Must published BMI percentiles for 6-74 years. Must proposed that 85th percentile indicates overwt and 95th centile to indicate obesity in children. They also stated that BMI below 5th centile provided a reference for underwt.

9. WHO – In 1995, a landmark measure was published by WHO It was that BMI = to or above 25 in an adult is overwt and obesity is BMI = to or above 30. The expert committee of WHO however did not define overwt and obesity in children very categorically. Thus we did not have a single measure.

10. International Obesity Task Force (IOTF) - In 2000, IOTF developed a method to predict BMI values appropriate for age in children equivalent to corresponding overwt and obesity in adults. They used data from multiple countries. Values were published for percentile equivalents to adult BMI 25, 30 & 18.5 for children between 2 to 18 years.

Table 2. gives the Salient landmarks in evolution of anthropometry[1,2,3,4,5]

Quetelet	Rohrer	Dugdale	Keys	Roche	Michillute	Burton
1823	1921	1971	1974	1981	1984	1985
BMI wt/ stature^2	Ponderal index wt/ stature^3	Dugdale index Wt/ht$^{1.6}$	BMI wt/ stature^2	BMI better index for girls. Subscap-ular thickness better for boys	BMI better correlated with triceps skinfold thickness	85th centile of BMI indicator of overwt. in children

.... ***Contd......***

Must	WHO	IOTF	Cole	WHO	WHO	IAP	IAP
1991	1995	2000	2007	2010	2013	2013	2015
85th centile of BMI - Overwt 95th centile of BMI obesity	Adults BMI = >25 Overwt BMI=>30 obesity. No measure for children	Percentile equivalents for BMI of 18.5, 25 & 30 published for children	Value of BMI 18.5 in children	BMI Z-scores in children 0-5 & 5-18 yrs & growth charts <-2SD & <-3SD	MUAC <11.5 cms or wt/ht <-3SD or bipedal oedema is severe acute mal-nutrition	Use WHO growth charts Z-score for SAM detection	IAP revised charts ht, wt, BMI for 5 to 18 yrs

11. Cole - Cole in 2007, published values equivalent to BMI of 18.5 for thinness in children.

12. WHO – In 2010, WHO published another definition using BMI Z-scores in children 0-5 & 5 to 18 years. It was de Onis & Lobstein who published WHO definitions of overweight & obesity using BMI.

13. WHO – In 2013, WHO defined SAM as MUAC <11.5 cms or wt/ht <-3SD or Z-score or bipedal oedema which is nutritional in origin.

14. I.A.P. (Indian Academy of Pediatrics) also decided to use WHO growth charts & use Z-score (or SD) for SAM detection in 2013.

15. I.A.P. – In 2015, I.A.P. revised charts for ht, wt, BMI for 5 to 18 yrs of age.

The most accepted measures are the WHO norms of 2013 defining severe acute malnutrition as MUAC below 11.5 cms or wt for ht below -3SD on WHO growth charts or bipedal oedema & MAM as MUAC between 11.5 to 12.5 cms and wt of ht between -3SD to -2SD. GAM means global acute malnutrition which includes both SAM & MAM. This is specially used for babies between 6 to 59 months to get a general idea about nutrition in a community.

Indian academy of Pediatrics[4] & many other national & international bodies adopted WHO definition of SAM & MAM.

Many workers have since then continued to measure MUAC & wt for ht. to detect wasting.

All ratios like Rao, Rao & Singh, Dugdale, Quetelet & Ponderal using weight and height need a special mention. Denominator height has been tripled in infants, squared in adults and as yet opinions are divided on how to use it for children from 1 to 5 yrs & 5 to 11 yrs.

Do MUAC & Wt for ht Detect the Same Set of Children?

Laillou Arnand[5] analyzed data from over 11000 children from Cambodia and found that with current MUAC of 11.5 cms as screening for SAM, over 90% children with a wt for ht. Z-score <-3 would have been missed. Reversely WHZ <-3SD missed 80% children with MUAC of less than 11.5 cms. Both measures thus identify different sets of children.

Fiorentino M, Sophonneary P, Laillou A[6] in a study on 14173 Cambodian children concluded that boys had higher MUAC cutoffs than girls except in 8-10.9 years' range. In children below 2 years MUAC cutoff was lower for stunted children compared to non-stunted.

Many studies have corroborated this finding, it has been observed by many workers that specificity and sensitivity of MUAC & Wt for ht is variable, and correlation is not absolute.

Can BMI be Used to Detect Thinness?

Many scientists have tried to use cutoffs to define thinness, overwt and obesity. de Onis & Lobstein[7] (WHO) in 2010 stated that for children below 5 yrs, thinness is defined as those with BMI below -2SD, overwt as those with BMI above 2SD & obesity as those with BMI above 3 SD. Thus, in one BMI chart measurement, a child could be categorized as thin, overwt or obese. The same workers found that for children above 5 years overwt is BMI >1SD & obesity is BMI >2SD. IO TF (Cole at 2000, 2007)[8,9] defined thinness as percentile equivalent of BMI <18.5, overwt as percentile equivalent of BMI >25 & obesity as >30.

Weight & Height Relationship

Relationship between weight and height is complex & enigmatic. Ponderal index of Rohrer wt/ht^3 is appropriate for infants, but it is not clear as to what formula can one apply to toddlers, young children or adolescents. Many studies have concluded that after 5 years of age wt/height^2 can be used. It was compared with triceps skinfold thickness and was found useful. Some difference was reported by race, sex and age. It was also seen that height influences BMI in children, with taller children having larger BMI to some extent. In some series, stunting was seen to be associated with overwt/obesity as measured by BMI. The results from different studies, in different ethnic populations have given differing results.

The issue therefore of whether to use BMI only for detection of undernutrion, overwt and obesity is partially resolved when we use WHO charts with SD or Z-score.

Role of MUAC in Detection of Malnutrition, Especially SAM & MAM

The main advantage of MUAC compared to other anthropometric measurements is that it is easy to perform, can be used by Anganwadi worker at the community level and requires just one non-stretchable tape costing few Rs. MUAC of less than 11.5 cms identified children at high risk of death in a series of longitudinal population studies that were undertaken in the 80's and early 90's[10]. They found MUAC to be a better diagnostic tool as it had the highest ROC (receiver operating characteristic)[10]. Aguayo VM[11] found that in 3 States of India, MUAC <115 mm appeared to be appropriate criterion to identify children with SAM who are at a greater risk of complications and death particularly 6-23 months' old children.

Unlike wt, MUAC is not affected by dehydration due to diarrhoea[12] MUAC specifically selects young children who have higher mortality. It also selects females more. MUAC has a relationship with fat mass and to some extent muscle mass. Survival is linked to fat stores during starvation and to muscle mass during infections[12,13]. Young children have comparatively low muscle mass that puts them at greater risk of death when they suffer from malnutrition. This may explain why wt for ht is not as effective as MUAC because it classifies in the same category children of different ages with same wt deficit not taking into account that young children with low muscle mass are at higher risk.

MUAC lacks sensitivity but is very specific. If more sensitivity is desired, higher MUAC cutoff may be used.

Wt. for ht. on the other hand detects a different set of people especially older children, boys and those with longer legs. Some workers feel that to increase sensitivity and specificity, one may combine MUAC and wt for ht while some workers feel it more appropriate to increase MUAC cutoff rather than combination of MUAC and wt for ht. WHO recommends that either MUAC or wt for ht Z-score are to be used to assess prevalence of SAM.

A study by Talapalliwar & Garg showed the sensitivity and specificity of MUAC <11.5 cm was 13.6% & 99.3% respectively. The best cutoff for screening of SAM was obtained at MUAC <12.8 cm where sensitivity and specificity was 50% & 90.8% respectively[14].

One study by Benitez Brito in adults showed that MUAC value ≤22.5 cms presented a sensitivity of 67.7% and specificity of 94.5% when compared to BMI <18.5[15]. Abdel Rahman[16] SM used MUAC Z-score in U.S. children 2 months to 18 years to generate data at all ages.

Relationship of MUAC, wt for ht, Infections and Survival

There are a number of studies that have shown that MUAC below 11.5 cms & Wt for ht <-3SD or Z-score identify different sets of children at different risk of deaths. The specificity of MUAC is higher than wt for ht to predict subsequent death[5]. It has been shown that MUAC is strongly related to fat mass in children but is related poorly to fat free mass or overall wt. As against that, wt for ht cannot discriminate between fat & lean body mass and therefore, reflects fat mass & lean body mass. Fat mass is linked to immune function through leptin produced in adipocytes. Leptin favours Th1 immune response. So, low MUAC will predispose a child to be at high risk of infection that needs typical Th1 response eg. viral infection[5]. Lean body mass is linked to immune response through different roles of amino acids in immune system like acute phase response, also glutamate, sulphur containing amino acids which are antioxidants through glutathione, arginine and are important for NO production. So, low wt for ht predisposes a child to get infections requiring humoral immune response (eg malaria)[5].

This also means that in some seasons when viral infections are common, MUAC measurement may play a role while in seasons when malaria is common wt for ht could be more relevant. Thus, different infection pressure can result in differential survival.

Skinfold Thicknesses

Skinfold thicknesses are measurements that provide an idea about subcutaneous fat deposits under the skin and total body fat. The procedure followed is that the skin is pinched at 8 skin fold sites and precision thickness calipers (Harpenden or Lange Holtaino) are applied. The areas are Triceps, Subscapular, Biceps, Suprailiac, Midaxillary,Quadriceps,Abdominal and Pectoral. The child or adult should be in standing position with shoulders relaxed while taking arm skinfold thicknesses. Right arm is preferred.

The formulae for fat calculation are separate for males and females and give body fat percentage. Body fat percentage above 25 % in males and above 30% in females is considered as obesity. Average is 14% in men and 26.9% in females. Other methods of calculating body fat are bioelectrical impedence analysis, X-ray analysis and the gold standard is water displacement method or hydrostatic weighing.

Four step formula

1. Step 1-Total body mass index(TBM) x % body fat = Fat mass wt (FW)
2. Step 2.TBM – FW=LBM lean body mass
3. Step 3 LBM / (1-GBF%)=TW
4. Step 4 TBM-TW=WL wt. loss TMI

For practical purposes, triceps skinfold thickness at the back of arm, biceps in front of arm,subscapular at 45^0 just below scapula and suprailiac in front of iliac crest on ant. abdominal wall are the 4 important measurements taken by calipers. All readings in mm are added.

Now , an example is cited.

A sum of 20 mm skinfold thicknesses for a 30 to 49 years old indicates 18.4%fat in females and 12.1% in males.

Similarly,

- 30 mm indicates 23.3% fat in females and 16.9% in males.
- 40mm indicates 26.8% fat in females and 20.3% in males
- 80mm indicates 35.6% fat in females and 28.8% in males.

For 30 to 49 years of age, 11 -17% is a good range for men and 15 - 23 % is a good range for females.

Arm Muscle Area (AMA) & Arm Fat Area

These can be derived from MUAC and skinfold thicknesses

Body Mass Exponential Index (BMEI)

This is an age independent anthropometric nutritional assessment devised by Manuel Cidras[17]. It is thought to be better than BMI as exponential index is better than power i.e. squared.

Problems Associated with BMI

Use of BMI as an anthropometric index of nutritional assessment from 2 to 20 years has always been difficult. Though BMI is considered by and large as the standard screening for nutritional status specially obesity, it is associated with several problems.

Taller children tend to have higher BMI and therefore higher probability of being diagnosed as obese. It may be a mathematical artifact than a biological one.

BMI varies in children on a U shaped line with nadir at 6 years of age.

BMI depends on leg length and in certain races it may result in erroneous values.

It depends on fat & non-fat wt. So athletes with increased muscle mass will have more wt. and will be wrongly labelled as obese.

Allometric growth of body i.e. growth of a part, at a different rate from that of the body as a whole cannot be best expressed as power function i.e. $height^2$. If one organ grows exponentially and the other in a linear fashion, the allometric relation should be exponential and not power. (Therefore, BMEI is thought to be better by some workers).

There is lack of consensus on four normal limits of BMI for age 5^{th} to 85^{th} centile as per CDC, 18.5 – 25 BMI percentile lines as per IO TF & ±2SD as per WHO

Manuel Cidras undertook statistical analysis and proved that BMEI wt/exp (2* height) is a better index and the curves drawn with this index coincide better with 5^{th} & 85^{th} centile. A BMEI of 2 with limits of 1.5 and 2.5 is useful for screening nutritional status during growth and the wt for ht chart is an ideal substitute for BMI for age chart.

Cidras has demonstrated that the wt, ht relationship from 2 to 20 years is better expressed by an exponential function than by a power function on which BMI is based. Wt/exp (2H) is more accurate than wt/ht^2, wt/ht^3 or wt/htp, in obtaining nutritional index[17].

Quetelet had considered growth coefficient to be ideally wt^2/ht^5 or $wt/ht^{2.5}$. The variation limit of 1.5 to 2.5 could be for females and males with 2 as the standard BMEI.

A BMEI of 2 with limits of 1.5 & 2.5 can then be used as nutritional index without requiring age chart.

Stunted children show inconsistent results. Some studies showed that stunting in early childhood was not related to BMI or adiposity. Other studies showed that stunted children were more likely to develop central adiposity[3].

Population differences related to ht & maturation can affect BMI.

There is a relationship between BMI & ht. Therefore, short children of China & tall Dutch population will need a scaling approach for adjustment of height & risk of adiposity. Here, wt for ht may be a better approach.

Stunted population may be a predictor of greater BMI. Asians may have a greater risk of chronic disease outcome at a lower BMI. Indian infants have a greater fat mass at any given wt compared to British infants[18]. Thus, though BMI continues to be a valuable measure for adiposity & though WHO defined thinness using BMI cutoffs in 2010, all these measurements are not yet ideal. The limitations of MUAC, wt for ht, BMI are discussed in the above paragraphs. In stunted children one may use waist circumference & skinfold thickness.

Percentage of wt. for height : This approach is partially age independent.

Rao & Singh[19,20] & Dugale[21] have studied it in details.

Rao & Singh showed that ($wt/height^{2}$)^{x100} was remarkably constant between 1-5 yrs and was same for males & females. The mean value was 0.15 (equaling to a BMI of 15?) and those with signs of malnutrition showed it to be 0.12 to 0.14. Dugdale described that $wt/ht^{1.6}$ provided the best index of anthropometric normality and was age independent. It remains to be studied if $wt/ht^{1.6}$ could replace BMI calculation of wt/ht^2. It may hold promise.

What Should be the Ideal BMI for Indians?

Answer to this question needs a lot more evidence to be generated. A low BMI with less body fat, thin lean, asthenic built may predispose to development of infections (Th2 cell dependent, rightly mycobacterium tuberculosis). Should we therefore change the lower limit of normal value of 18.5 BMI to around 20? Similarly, because Asian bodies have more fat than muscle mass[15,18] should we change the value of upper limit of normality from 24.9 to around 23? Further evidence will answer these questions. Should we use $wt/ht^{1.6}$ to replace the conventional BMI and generate one chart that will detect SAM, MAM, normal, overwt, obese children & adults of all ages? The answer will be obtained through large international studies. Indian Academy of Pediatrics[22] has already revised growth charts for Ht, Wt & BMI for 5 to 18 year old children. One may think of applying Dugdale Index[21] afresh and workout its specificity & sensitivity with MUAC in detection of SAM and its relation to BMI cutoffs in detecting obesity so as to arrive at a common measure for all. TMI- Triponderal mass index could be tried out in the same way as Dugdale. All these evidences so generated will probably arrive at one standard measure that could detect under wt and obesity in all age groups.

References

1. WHO Child Growth Standards. Acta Pediatr supplement 2006; 450:5-101.
2. de Onis M, Lobstein T, 2010. Defining obesity risk status in the general childhood population which cutoffs should we use? International J. of Ped. Obes 5(6), 458-460.
3. Colleen M Doak, Daniel J Hoffman, Shane A Norris, Maiza Campos. Ponce, Katja Polman, Paul L. Griffiths 2013. Global food security 2, 65-71.
4. Dalwai S, Chaudhari P, Bavdekar SB et al 2013. Consensus Statement of Indian Academy of Pediatrics on IMSAM, Ind. Pediatr 50(4): 399-404.
5. Arnand Laillou, Sophonneary Prak, Richard de Groot, 2014. Optimum screening of children with acute malnutrition requires a change in current WHO guidelines as MUAC and WHZ identify different patient groups. Plos one Jul 1. doi : 10.1371.
6. Fiorentino, Sophonneary, Laillou, Whitney S, 2016. Current MUAC cutoffs to screen for acute malnutrition need to be adapted to Gender and Age. Plos one Feb 3, 11(2): e0146442, doi : 10.137.
7. de Onis M, Lobstein T 2012. Extended international (10 TF). BMI cutoffs for thinness, overwt & obesity. Pediatric obesity 7(4), 284-294.
8. Cole TI, Bellizzi Mc, Flegal 2000. Establishing a standard definition for child overwt & obesity worldwide. International survey Br Med J 320, 1240-1243.

9. Cole TJ, Flegal KM, Nicholis D 2007, BMI cutoffs to define thinness in children & adolescents: international survey Br Med J 335 (7612), 194.
10. Andre Briend 2012, Use of MUAC for SAM. CMAM forum 1-4.
11. Aguayo VM, Aneja S et al 2015 MUAC is an effective tool to identify infants & children with SAM in India. Pub. Health Nutr. 17:3244-8.
12. Modi P, Nasrin S, Hawes M et al 2015. MUAC out per forms wt based measures of nutritional status in children with diarrhoea 2015. J.Nutr. 145 (7) : 1582-7.
13. Trowbridge FL, Hiner CD & Robertson AD 1982. Arm muscle indicators and creatinine excretion in children, Am. J. Clin. Nutr. 36 (4) : 691-6.
14. Talapalliwar M, Garg B 2016. Diagnostic accuracy of MUAC for detection of SAM & MAM. Int. J. of Med. Sc. & Publ. health, Vol 5, 7: 1317-1321.
15. Benitez B N, Suarez Llanos J.P., Fuentes FM et al 2016, Relationship between MUAC & BMI in patients, 11(8): e0160480.
16. Abdel – Rahman SM, BiC 2017, Nutr Clin Pract 32(1) 68-76. Construction Lambda, MU, Sigma values for determining MUAC Z-scores.
17. Cidras M 2015. Body mass exponential index. Open access libr.jour. 2:e1943. http://dx.doi.org/10.4236/O alib 1101943.
18. Yajnik C S, Fall CHD, Coyaji K J et al 2003. Neonatal anthropometry: the thin fat baby. Int. J. of obesity 27, 173-180.
19. Rao K V, Singh D 1970, AM J. Clin. Nutr 23, 83.
20. Dugdale AE & Edkins E 1964, Lancet 1,1062.
21. Dugdale AE 1971. Am J. Clin. Nutr 24, 174.
22. Khadilkar V, Yadav S, Agarwal K K et al 2015, Revised IAP growth charts for Ht, Wt & BMI for 5 to 18 year old Indian Children, Ind Pediatr. 52; 47-55.