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IN SEARCH OF A DEFINITION OF CHILDHOOD OBESITY

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ABSTRACT

Childhood obesity is manifested when there develops a discrepancy between intake and output of energy, disturbing the original steady state and formation of a fresh steady state at a higher level, resulting in increased body-fat storage. There needs to be a delicate balance established between tissue synthesis (height gain) and fat storage (mass gain) in order to prevent obesity. Various definitions of childhood obesity have been proposed. During 1995-2001, Poskitt, representing European Childhood Obesity Group (ECOG), tried to deal with this issue. In a 1995 paper, she expressed concern over lack of childhood-obesity definition. In 2000, she mentioned that the concept of relative body-mass index (*BMI*) had been generally accepted. In 2001, she observed that *BMI* could not be considered as offering the 'best' definition, although it might be 'useful' and 'practical'. In 2000 Cole and co-workers linked childhood obesity to adult-obesity-cutoff point (*BMI* 30 kg/m^2). In a 2010 paper, Flegal and co-workers gave 3 *BMI*-for-age categories**:** 'normal', 'intermediate' and 'high'. The first one *most unlikely*, whereas the last one *most likely*, to have high adiposity. In a 2011 paper, Rolland-Cachera and co-workers, on behalf of ECOG, defined 3 cutoffs of *BMI*, constituting four ranges**:** 'thin', 'normal', 'overweight' and 'obese'. During the same year, Zhao and Grant defined obesity as excess of body fat. In a 2015 paper, Al-Gindan and co-workers expressed the opinion that most national-survey analyses equating *BMI* in excess of 30 kg/m^2 with 'obesity' led to survey-data misinterpretation. This paper puts forward the point-of-view that 'overweight' must be differentiated from 'overfat'. One needs a definition based, solely, on measurement of mass, not measurement of fat, which is difficult to obtain in a reproducible manner. Childhood obesity has been defined as the condition in which a youngster is required to shed off net mass at the end of 6-*month* period as compared to current mass based on 'Growth-and-Obesity Vector-Roadmap' recommendations. In this work, '*BMI*-based-optimal mass' is compared with 'height-percentile-based-optimal mass' and mathematical relationship is proposed for losing net mass within the next 6 *months*.

Keywords: Body-mass index (*BMI*), *BMI*-based-optimal mass, estimated-adult *BMI*, height-percentile-based-optimal mass, Growth-and-Obesity Vector-Roadmap, month-wise height- and mass-management targets

LIST OF ABBREVIATIONS

*cm***:** centimeter(s) • *m***:** meter(s) • *ft***:** foot(feet) • *in***:** inch(es) • *lb***:** pound(s) • *oz***:** ounce(s) • *kg***:** kilogram(s)

AM:	**A**cute **M**alnutrition
BMI:	**B**ody-**M**ass **I**ndex
CDC:	**C**enters for **D**isease **C**ontrol and **P**revention, Atlanta, GA, United States http://www.cdc.gov
EC I:	**E**nergy-**C**hannelization **I**
EC II:	**E**nergy-**C**hannelization **II**
EC III:	**E**nergy-**C**hannelization **III**
ECOG:	**E**uropean **C**hildhood **O**besity **G**roup
MP:	**M**id-**P**arental
NGDS:	**N**ational **G**rowth and **D**evelopmental **S**tandards for the Pakistani Children http://ngds-ku.org
ON:	**O**ver-**N**utrition
SGPP:	**S**ibling **G**rowth **P**ilot **P**roject
UN:	**U**nder-**N**utrition

INTRODUCTION

Obesity has become a universal problem among children. Childhood obesity may be connected to grave physical, psychological and social consequences. One of the contributing factors may be socioeconomic disparity among different factions of society. Obesity in children may be linked to serious psychological, physical and social consequences resulting in impaired economic, educational and social productivity. Not long ago, First Lady the of United States, **Her Excellency, Michelle Obama** declared childhood obesity an epidemic for her country. The disease is contributing, significantly, to adult obesity, diabetes as well as non-communicable diseases. Hence, it becomes important to detect the problem at an early stage to plan and to implement efficient and effective intervention strategies.

Lack of a universally agreed definition of childhood obesity has further complicated the problem. In the absence of such a definition, it becomes difficult to decide which group of children to treat and which not to treat.

In this work, effectiveness of '*BMI*-based-optimal mass' is compared with 'height-percentile-based-optimal mass' to classify childhood obesity. Further, a mathematical relationship is put forward for losing net mass within 6 *months*.

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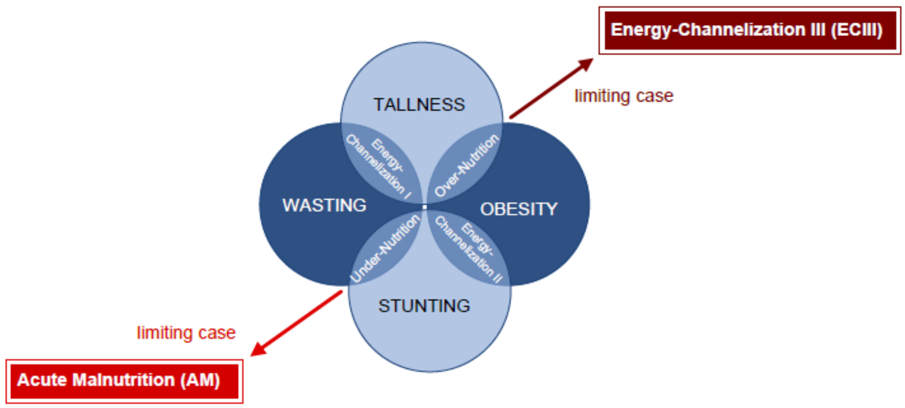


Fig. 1. Venn-diagrammic representation of nutritional-status classification — Venn-diagrammic classification proposed in Kamal *et al*. (2014*b*), limiting cases introduced in Kamal (2015*b*) and discussed in detail in Kamal *et al*. (2016*c*)

CHILDHOOD OBESITY DEFINITIONS

Obesity develops when there exists a discrepancy between intake and output of energy, disturbing the original steady state and formation of a fresh steady state at a higher level, resulting in increased body-fat storage (Wabitsch, 2000), essentially becoming an energy-channelization problem (Figure 1). The author described steady state as a situation from both energy-transfer and probability-of-occupation perspectives (Kamal, 2011). The first one pictures the situation in which the transfer of energy occurs at a uniform rate. The second one embodies the concept that the probability of occupation is not the same in different states. However, it does not vary with time. The fragile balance between tissue synthesis (height gain) and fat storage (mass gain), if mathematically modeled, may prevent obesity (Figure 2). According to Poskitt (1995), representing European Childhood Obesity Group (ECOG), lack of childhood-obesity definition has been a matter of concern for the group. A relative *BMI* (body-mass index) can be developed as *BMI* of a 50th *centile* child — For a grown-up person, *BMI* may be computed by dividing mass (in *kilograms*) with square of height (in *meters*). In a subsequent paper, Poskitt (2000) mentions that the concept of relative *BMI* has been generally accepted despite considerable imprecision in defining obesity. In a 2001 paper, she states that *BMI* can not be considered as offering the 'best' definition, although it might be considered as the most 'useful' and 'practical' one for clinical, epidemiological and population-research purposes (Poskitt, 2001). She, further, adds that work on definition is essential and needs continuing reassessment, although one cannot wait for the perfect definition. Cole *et al*. (2000) defines childhood obesity based on pooled-international data and links to adult-obesity-cutoff point of *BMI* to be 30 kg/m^2; the definition being less arbitrary and more international than others and it should encourage direct comparison of global trends in childhood obesity. Using the recommendations of American Medical Association Expert Committee, Flegal *et al*. (2010) divided *BMI*-for-age categories into three ranges: 'normal', 'intermediate' and 'high'. The first one *most unlikely*, whereas the last one *most likely*, to have high adiposity. Rolland-Cachera *et al*. (2011), on behalf of ECOG, defined three main cutoffs of *BMI* distribution status from the age of 5 *years*, constituting four ranges: 'thin', 'normal', 'overweight' and 'obese'. Zhao and Grant

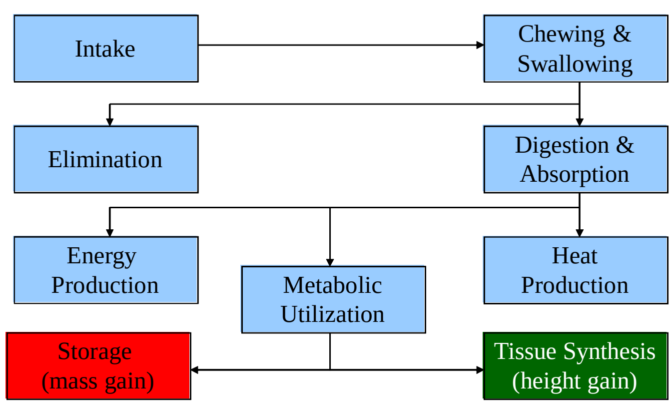


Fig. 2. Childhood obesity may be managed through a delicate balance between storage (mass gain resulting in 'obesity') and tissue synthesis (height gain resulting in 'tallness') — adapted from Fig. 4 of Kamal and Jamil (2014)

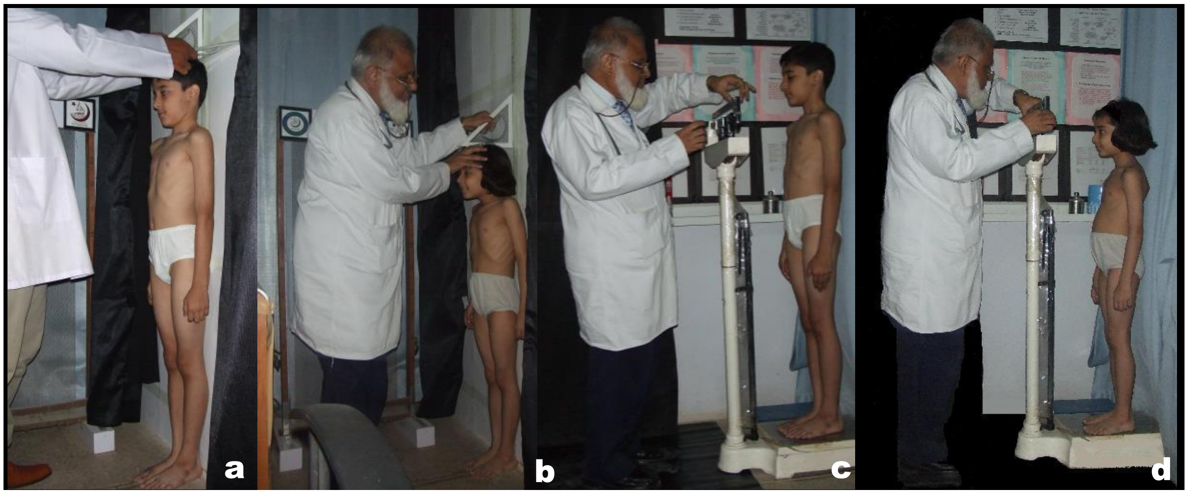


Fig. 3*a-d*. Height and mass measurements in SF-Growth-and-Imaging Laboratory — (*a*), (*c*) first appeared in Kamal and Jamil (2012), whereas (*b*), (*d*) appeared in Kamal and Jamil (2014); the two sets printed in the same journal

(2011) observe that obesity involves interactions between genetic and environmental factors. They identify obesity as excess of body fat. Skinner and Skelton (2014) define overweight and obesity in children as those having *BMIs* greater than 85th and 95th percentiles, respectively. Al-Gindan *et al*. (2015) are of the opinion that *BMI* remains the most common method for classifying thinness and fatness, despite having a weaker correlation with body-fat content. Further, *BMI* does not distinguish 'fat mass' from 'muscle mass'. These two masses have opposite implications for health and well-being. They warn that most national-survey analyses, equating *BMI* in excess of 30 kg/m^2 with 'obesity', lead to survey-data misinterpretation. Ogden *et al*. (2016) consider *BMI* as an imperfect measure of body fat and health risk. The prime argument is that there are racial and ethnic differences in body fat at the same *BMI* level. They further observe that, among children, the definition of obesity is purely statistical.

THE NGDS PILOT PROJECT

Initiated in 1998, the NGDS (National Growth and Developmental Standards for the Pakistani Children) Pilot Project complies with the applicable human-right protocols (Kamal *et al*., 2002).

Project Protocols

The NGDS Pilot Project is being conducted in 4 representative schools (one civilian and one each operated by the Armed Forces of Pakistan). A subproject, named as SGPP (Sibling Growth Pilot Project) catered to the health of families, who came to SF-Growth-and-Imaging Laboratory along with their 5-10-*year*-old children, for checkups. The checkups are conducted giving due regard to participants' comfort, confidentiality, dignity, privacy and safety. Additional File 1 (http://www.ngds-ku.org/Papers/J45/Additional_File_1.pdf) gives details of checkup protocols.

Anthropometric Techniques

Heights, h, and masses, μ, were measured by trained anthropometrists, with documented reproducibility, as per protocols given in (Kamal, 2006) to least counts of 0.1 *cm* (1998-2011, setsquare); 0.01 *cm* (2012-2015, Vernier scale); 0.005 *cm* (2016-present, enhanced-Vernier scale) and 0.5 *kg* (1998-2011, bathroom scale); 0.01 *kg* (2012-2015, modified-beam scale); 0.005 *kg* (2016-present, enhanced-beam scale), respectively, before noon, with the children completely undressed except short underpants (Figure 3). The measuring instruments were calibrated at the start of each daily session and zero errors noted. Total disrobing ensured that the measurers were able to ascertain proper posture (Frankfort horizontal/auriculo-orbital plane parallel to floor, elbows and knees not flexed, heels/toes not lifted, feet together for height measurement/feet apart for mass measurement) and complete inhaling (forces the child to assume upright posture).

Extended CDC Growth Charts and Tables

'Growth-and-Obesity Vector-Roadmaps' (Kamal *et al*., 2016*a*; *b*), which replaced 'Growth-and-Obesity Scalar-Roadmaps' (Kamal, 2015*a*; *b*; Kamal *et al*., 2015) are used to investigate childhood obesity. These are generated using 'Extended CDC (Centers for Disease Control and Prevention) Growth Charts and Tables' listed in Additional

September 4, 2013	1st-Generation Solution of Childhood Obesity (Kamal *et al.*, 2013*f*)	
September 4, 2014	2nd-Generation Solution of Childhood Obesity (Kamal *et al.*, 2014*a*)	
June 1, 2015	3rd-Generation Solution of Childhood Obesity (Kamal, 2015*a*)	
February 13, 2016	4th-Generation Solution of Childhood Obesity (Kamal *et al.*, 2016*b*)	
January 1, 2017	5th-Generation Solution of Childhood Obesity (this work)	

Fig. 4. Solutions of childhood-obesity problem proposed in SF-Growth-and-Imaging Laboratory, University of Karachi

File 3 of Kamal and Jamil (2014). The extended charts and tables contain 0.01th, 0.1th, 1st, 99th, 99.9th and 99.99th *percentile* entries in addition to usual entries of height and mass in the range 3rd to 97th percentiles.

Modeling of Childhood-Obesity Problem

Modeling of childhood obesity problem started in 2002, with the concept of 'height-percentile-based-optimal mass' mentioned in 2004 and formally defined in 2011, when 'Growth-and-Obesity Profiles' of a family were introduced, which included concepts of degree of wasting/obesity and stunting/tallness expressed as percentages (Kamal *et al.*, 2002; 2004; 2011). In 2012, estimated-adult *BMI*, giving a snapshot of obesity status of a fully-grown child (boys 21 *years*; girls 19 *years*), was formulated (Kamal and Jamil, 2012). During 2013-2016, 1st- to 4th-generation solutions of childhood obesity were proposed (Figure 4) — 1st- to 3rd-generation solutions are summarized in Kamal (2015*c*).

DEFINITION OF CHILDHOOD OBESITY ADAPTED BY THE NGDS TEAM

The author is of the opinion that 'overweight' (classified based on measurement of 'net mass' — mass obtained without any clothing) needs to be distinguished from 'overfat' (classified based on measurement of skinfolds as well as waist and hip circumferences). Weiss *et al.* (2004) observe that body proportions normally change during pubertal development making it difficult to interpret waist-to-hip ratios in children. The method becomes even more ineffective as there are racial and ethnic differences in different pediatric populations. Hence, it is obvious that one needs a definition based, solely, on measurements of mass and height; not measurement of fat, which is difficult to obtain in a reproducible manner (Kamal *et al.*, 2013*g*). Kamal and Razzaq (2014) investigated reproducibility of mass measurement to least count of 0.01 *kg*. Starting from 2016, masses and heights can be recorded to least counts of 0.005 *kg* and 0.005 *cm*, respectively, in SF-Growth-and-Imaging Laboratory (Kamal *et al.*, 2016*b*).

The author defined childhood obesity as the condition in which the youngster is required to shed off net mass at the end of 6-*month* period as compared to current mass based on 'Growth-and-Obesity Vector-Roadmap' recommendations (Kamal, 2016).

Height-Percentile-based Optimal Mass vs. BMI-based-Optimal Mass

'Height-Percentile-based-Optimal Mass' (Kamal *et al.*, 2004; 2011) was defined as the mass, whose percentile, computed from the Extended CDC Growth Table for mass, was identical to height percentile (Kamal *et al.*, 2011). 'Estimated-Adult *BMI*' (Kamal and Jamil, 2012) was computed by replacing estimated-adult values of height and mass in *BMI* formula (Figure 5).

'*BMI*-based-Optimal Mass' for an adult (above the age of 20 *years*) is computed by taking the value 24 kg/m^2 as standard, representing normal weight-for-height

Nomenclature	*Represented by*	*Mathematical Expression*	*References*
Body-Mass Index	*BMI*	μ/h^2	Keys *et al.* (1972)
Estimated-Adult Body-Mass Index	$BMI_{estimated\text{-}adult}$	$\mu_{estimated\text{-}adult}/h_{estimated\text{-}adult}^2$	Kamal and Jamil (2012)
Height-Percentile-based-Optimal Mass	μ_{opt}	$P(\mu_{opt}) = P(h)$	Kamal *et al.* (2004; 2011)
BMI-based-Optimal Mass	μ_{BMI}	Next page	This work

Fig. 5. Various indicators used to classify childhood obesity

(1) $\mu_{\text{BMI}} = 24h^2$, h (height) in m

'*BMI*-based-Optimal Mass' for a growing child was computed in three steps. In the first step, 'Estimated-Adult-*BMI*-based-Optimal Mass' was evaluated using the expression

(2) $\mu_{\text{BMI-estimated-adult}} = 24h_{\text{estimated-adult}}^2$, $h_{\text{estimated-adult}}$ (estimated-adult height) in m

In the second step, 'Percentile for *BMI*-based-Optimal Mass', $P(\mu_{\text{BMI}})$, was estimated using linear interpolation applied to estimated-adult-*BMI*-based-optimal mass. In the third and the final step, box interpolation (Kamal *et al*., 2011) was used to compute *BMI*-based-optimal mass at the given age. Appendix A includes Tables A1-5*a*, which illustrate some worked examples. Additional File 2 (http://www.ngds-ku.org/Papers/J45/Additional_File_2.pdf) shows step-by-step calculations ('*BMI*-based-Optimal Mass' as well as 'Growth-and-Obesity Vector-Roadmap') of case 1 (M. E./SGPP-KHI-20100421-03/01).

Possible Candidates for Classification as Obese Children

The possible candidates for classification as obese children must have percentile of mass greater than percentile of height at the time of the most-recent checkup. Five such cases are analyzed. Appendix A lists their 'Growth-and-Obesity Vector-Roadmaps' adapted to include *BMI*-based-optimal mass and the corresponding percentile as well as month-wise recommendations of mass of height management. Additional File 3 (http://www.ngds-ku.org/Papers/J45/Additional_File_3.pdf) explains color-coding used in these 'Growth-and-Obesity Vector-Roadmaps'.

RESULTS

Tables A1-A3*a*, *b*, A5*a*, *b* and 4*a*-*c* (Appendix A) present customized Growth-and-Obesity Vector Roadmaps of 5 children, who might be classified as obese as they happen to have their mass percentile exceeding height percentile at the time of their last checkup.

A comparison of *BMI*-based-optimal mass and height-percentile-based-optimal mass as well as the corresponding percentiles in all 5 cases reveals that *BMI*-based-optimal mass (corresponding to normal *BMI* taken as 24 kg/m^2) and the corresponding percentile are inadequate to represent non-obese children (Table 1). These masses are far above than the height-percentile-based-optimal masses. During the checkups, the NGDS Team noticed that children, who were classified as normal according to height-percentile-based-optimal-mass criterion, were perceived to be overweight as per standards of the Pakistani community. It is to be appreciated that normal and overweight is somewhat a subjective term and the classification varies from community to community as the comparison is based on the average in that particular community.

An examination of month-wise-mass-management recommendations listed in Tables A1-A3*b*, A4*c* and A5*b* reveal that a net loss of mass is suggested only in cases 1 (M. E./SGPP-KHI-20100421-03/01) and 5 (Z. J./SGPP-KHI-20060412-01/01) . Differences of percentile of mass at the time of the most-recent checkup and the reference

Table 1. Comparison of *BMI*-based-optimal mass and height-percentile-based-optimal mass

Case No.	*Initials*	*Checkup*	P_{ref}	$P(h)$	$P(\mu)$	$P(\mu_{\text{BMI}})$	$\Delta\mu = \mu_{\text{BMI}} - \mu_{\text{opt}}$	$\Delta P = P(\mu_{\text{BMI}}) - P(h)$
1	M. E.	1st	47.49	39.72	75.79	64.46	+3.46	+24.74
		2nd	47.49	34.34	63.42	62.05	+4.11	+27.71
2	Q. H.	1st	53.51	53.51	90.93	70.61	+1.39	+17.10
		2nd	42.36	42.36	87.07	65.61	+2.06	+23.25
		3rd	37.69	37.69	45.23	63.54	+2.80	+25.85
3	Z. I. R.	1st	19.36	4.97	17.20	39.94	+4.13	+34.97
		2nd	19.36	4.96	19.36	39.91	+4.33	+34.95
4	Z. H. Z.	1st	76.12	46.42	26.81	67.43	+1.84	+21.01
		2nd	76.12	46.65	26.09	67.53	+2.15	+20.88
		3rd	76.12	47.02	29.25	67.70	+2.20	+20.68
		4th	76.12	4.54	46.25	38.89	+4.50	+34.35
		5th	76.12	58.22	63.50	72.73	+2.59	+14.51
5	Z. J.	1st	23.18	23.18	78.36	56.76	+6.14	+33.58
		2nd	26.76	26.76	82.41	58.72	+6.23	+31.96
		3rd	36.69	36.69	80.85	62.88	+5.86	+26.19

Table 2. Analysis of various cases

Case No.	Initials	Conditions for Percentiles		Worked Examples		$P(\mu, A_0) - P_{\text{ref}}$
		$P(h, A_0)^{\nabla}$	$P(\mu, A_0)^{\nabla}$	Tables	Figure$^{\otimes}$	
1	M. E.	$P(h, A_0) < P_{\text{ref}}$	$P(\mu, A_0) > P_{\text{ref}}$	A1*a*, *b*	AFIII-1	**+15.92691543307139**
2	Q. H.	$P(h, A_0) = P_{\text{ref}}$	$P(\mu, A_0) > P_{\text{ref}}$	A2*a*, *b*	AFIII-2	+7.5399244537494
3	Z. I. R.	$P(h, A_0) < P_{\text{ref}}$	$P(\mu, A_0) = P_{\text{ref}}$	A3*a*, *b*	AFIII-3	0
4	Z. H. Z.	$P(h, A_0) = P_{\text{ref}}$	$P(\mu, A_0) < P_{\text{ref}}^{\exists}$	A4*a-c*	AFIII-4	–12.61808090540289
5	Z. J.	$P(h, A_0) = P_{\text{ref}}$	$P(\mu, A_0) > P_{\text{ref}}$	A5*a*, *b*	AFIII-5	**+44.1605237694329**

$^{\nabla}P(h, A_0)$ and $P(\mu, A_0)$ represent percentiles of height and mass measured at the most-recent checkup.

$^{\otimes}$Figures in Additional File 3 show navigational and guidance trajectories as well as recommended control action.

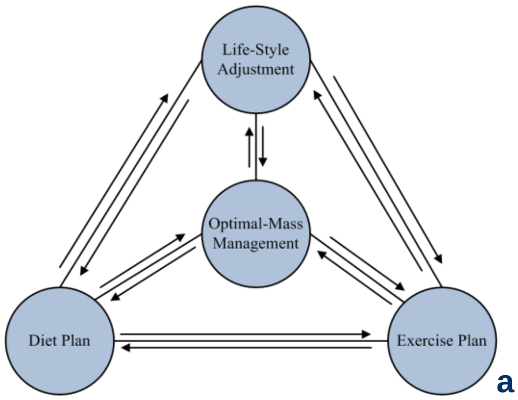
$^{\exists}P(\mu, A_0) > P(h, A_0)$

percentile (maximum of percentiles of measured height, mid-parental height and army-cutoff height) in cases 1 and 5 come out to +15.93 and +44.16, respectively, whereas in cases 2, 3 and 4, these differences come out to +7.53, zero and –12.62, respectively (Table 2). From, this preliminary analysis, it is suggested to classify a child as obese for whom this difference is more than +15.

DISCUSSION AND RECOMMENDATIONS

The management of childhood obesity is considered to be a problem of energy-channelization (Figure 1) by maintaining a delicate balance between 'storage', resulting in weight gain and subsequent obesity, if not accompanied by an equivalent pick up in height and 'tissue synthesis' resulting in height gain/tallness, which may end up making the child wasted if not accompanied by an equivalent weight put on (Figure 2). Optimal-mass management may be visualized as optimal solution of lifestyle adjustment combined with appropriate diet and exercise plans (Figure 6*a*). It is to be noted that all diet-based interventions to overcome obesity shall be ineffective if the child is suffering from vitamin-D deficiency (Figure 6*b*). The author would like to put forward the following recommendations for management of childhood obesity:

- Prior to any intervention to manage mass, at-risk children must be subjected to complete, stripped physical examinations combined with psychological and fitness testing (Kamal *et al*., 2017*a*).
- The above examinations should include recordings of height and mass (weight) of children (Figures 3*a-d*) as well as height measurement of both biological parents to generate Growth-and-Obesity Vector-Roadmaps, which provide height and mass targets to be achieved every month for the next 6 *months* (Kamal *et al*., 2016*a*).
- Positive reinforcement through honor-rolls, rewards and scholarships may help persuade students to achieve and maintain optimal mass-for-height (Hunsberger *et al*., 2016).



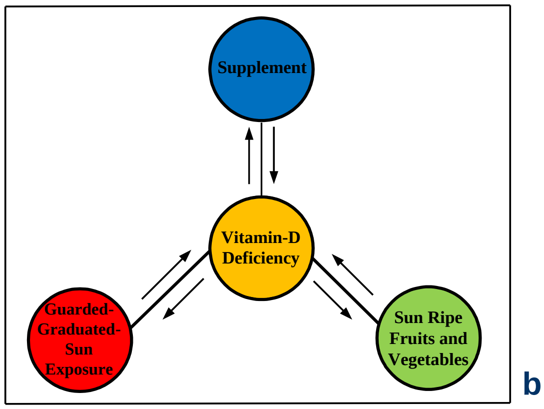


Fig. 6*a*, *b*. Optimal-mass management could be visualized as optimal solution of lifestyle adjustment, diet and exercise plans; measures to overcome vitamin-D deficiency — (*a*) first appeared in Kamal *et al*. (2014*b*); printed in the same journal

Table 3. Lifestyle adjustment, diet and exercise plans for a child to achieve month-wise targets of gaining height and shedding-off mass (weight)

<table>
<tr><th></th><th>Height Management[#]</th><th>Mass (Weight) Management[#]</th></tr>
<tr><td>Lifestyle Adjustment</td><td colspan="2">Recommended daily dose of vitamin D (600 IU) through 10-15 minute guarded-graduated[∈] sun-exposure (early morning or late afternoon) with the child minimally dressed (leaving head, arms, legs and spinal column exposed, last one from external auditory meatus to hip joint; eyes protected through UV-cutoff glasses); 1-2 hour fresh air exposure to uncovered skin; hair and body massage with olive oil before bathing; 8-hour, night-time, sound sleep dressed in pajama shorts only[@] (3-minute, slow-stoke back massage to improve quality and quantity of sleep); maximum 2-hour screen time (one hour computer/video games — computer monitor at eye level, neck and back straight and normal to thighs; one hour TV/DVD — light exercises during TV/DVD watching)</td></tr>
<tr><td rowspan="2">Diet Plans</td><td colspan="2">3 relaxed and balanced meals, 10-12 glasses of water daily — absolutely NO carbonated drinks[&]</td></tr>
<tr><td>To gain height, diet plan should include calcium-, protein- and fiber-rich diet (milk, fresh fruit, chicken and fish)</td><td>To shed off mass (weight), diet plan should include salad, yogurt and skimmed milk</td></tr>
<tr><td rowspan="2">Exercise Plans</td><td colspan="2">Exercises for 5 minutes each after waking up, at the end of every hour and before going to bed — bending on sides, focusing eyes far away and moving eyeballs, moving fingers and wrists after computer work and writing, stretching, touching toes without flexing knees, exercising neck muscles (left, right, up, down). Structured exercises, guarded-graduated[©], exercises preceded by warm-up and followed by cool-down routines, preferably outdoors (weather permitting) in exercise-friendly clothing[ɜ]</td></tr>
<tr><td>To pick up height, child should perform light-stretching exercises (bar hanging, mild-stretching, summersault, cartwheel)</td><td>To lose mass (weight), child should perform light exercises for longer duration, consistently</td></tr>
</table>

[#]Lifestyle-adjustment guidelines are taken from (Kamal *et al.*, 2013*a*), height-management from (Kamal *et al.*, 2013*b*) and mass-management from (Kamal *et al.*, 2013*e*).

[∈]'Guarded' implies surveillance of overexposure, which may produce skin burn (short term) and skin cancer (long term); 'graduated' means systematic increase in exposure for body conditioning (Kamal and Khan, 2015).

[@]Sleeping in day clothes or underwear should be discouraged. In gender-segregated sleeping quarters, boys of all ages and younger girls should be encouraged to sleep stripped-to-waist, allowing the body to breathe and increasing tactile stimulation (Kamal and Khan, 2014).

[&]Carbonated drinks take away body's capacity to absorb calcium and iron and hence should be avoided, not only, by children, but also, by persons of all ages, in particular, older individuals.

[ɜ]Details of exercise-friendly clothing are given in Kamal and Khan (2015).

[©]Guarded-graduated exercises should contribute towards health- as well as skill-related fitness (performance considerations). Such practices, also, avoid exercise-related injuries (safety considerations). 'Guarded' is related to the concept that different body ligaments are in stable equilibrium, locally, during different exercise phases and 'graduated' implies that sequential exercise phases are related by infinitesimal transformations (Kamal and Khan, 2013).

- The mathematically determined targets should be achieved through a combination of lifestyle adjustment, diet and exercise plans (Table 3).
- At times, instead of reducing mass (weight), it may be a better option to increase height, so that excess weight is balanced through height pick up. This becomes particularly important, when the reference percentile is either coinciding with the army-cutoff-height percentile (Kamal *et al.*, 2017*b*), as in case 3, representing roadmap of Z. I. R., or with the mid-parental-height percentile, as in case 4, representing roadmap of Z. H. Z. (Kamal, 2015*a*).
- Obesity management should be considered a family affair, with counseling and education provided for the entire family.
- More frequent monitoring of height and weight is needed for children in the high-risk group (Campbell and Haslam, 2006) — family history of obesity, children with learning disabilities, children of low-income groups, children of migrant families.

FUTURE DIRECTIONS

There is a need to validate the proposed criterion of critical difference of percentile of mass and reference percentile through samples drawn from international population and using growth charts and tables other than those used in this work (Extended CDC Growth Chats and Tables). Suitability of use of *BMI*-based-optimal mass vs. height-percentile-based optimal mass should, also, be investigated for children under the age of 10 years based on international samples. In order to overcome childhood-obesity epidemic, the issue should be addressed from a multidisciplinary perspective by providing rationale for (height-percentile-based- as well as *BMI*-based-) optimal mass, not only, from mathematics, but also, from physiology and biophysics (Apell *et al.*, 2011). Diet and exercise plans should be fine-tuned to account for actual calories, which need to be burnt during a month.

CONCLUSION

This work tried to streamline various definitions of childhood obesity. Merits and demerits of different indicators of childhood obesity were discussed. It was concluded that a child should be considered obese, when the incumbent's Growth-and-Obesity Vector-Roadmap generates recommendation of a net loss of mass (weight) during the next 6 *months,* which was related to the difference of percentile of mass and the reference percentile (maximum of percentiles of height, mid-parental height and army-cutoff height).

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Already known on this topic

Childhood obesity a serious public health concern

————

Obesity a complex disease that involves interactions between environmental and genetic factors

————

The true prevalence of childhood obesity difficult to empirically quantify as there is currently no internationally-accepted definition

————

BMI still the most popular method of classifying fatness and thinness

————

Various definitions obesity proposed included relative *BMI*, cutoff point as 30 *kg*/*m*² (adult *BMI*), *BMI* ranges (below 85th percentile: normal, 85th to 95th percentile: intermediate, equal to or above 95th percentile: high)

SF-Growth-and-Imaging Laboratory contributions

2004 Optimal mass (mention of name; formal definition in 2011)

————

2011 Statuses (pertaining-to-mass) and (pertaining-to-height)

————

2012 Estimated-adult *BMI*

————

2013-2016 1st- to 4th-generation solutions of childhood obesity

————

2014 Energy-channelization I-III, which included puberty-induced energy-channelization

————

2014 Pseudo-gain of mass and height

————

2014 Use of height- and mass-percentile trajectories instead of growth (height) velocity and rate of mass gain/loss

————

2014 CDC Growth Tables extended to include percentiles in the range 0.01th to 99.99th (to handle extreme cases)

————

2015 Month-wise targets (next 6 *months*) to shed-off mass

————

2016 Mass and height measurements to least counts of 0.005 *kg* and 0.005 *cm*, respectively, accompanied by manual, version 9.1

This work adds

Mathematical definition of childhood obesity — A child is considered obese if the incumbent is required to lose net mass (weight) within the next 6 *months;* this happens when the difference of percentile of mass exceeds reference percentile (maximum of percentiles of measured height, mid-parental height and army-cutoff height) by 15

————

Comparison of *BMI*-based-optimal mass and height-percentile-based optimal mass, indicating that *BMI*-based-optimal mass does not differentiate between normal and obese child in the context of the Pakistani children

————

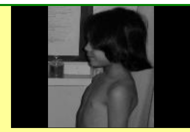
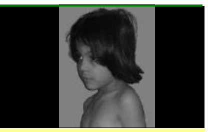
5th-generation solution of childhood obesity

The next step

Validation of mathematical definition of childhood obesity using samples drawn from international studies

Table A1*a*. Growth-and-Obesity Vector-Roadmap of M. E. (SGPP-KHI-20100421-03/01)

Gender: Female • *Date of Birth* (*year-month-day*): 2002-09-23 • *Army-Cutoff Height*: 157.48 *cm* (19.36[P])[§]
Father's Height: 167.80 *cm* • *Mother's Height*: 171.00 *cm* • *Target Height*: 162.90 *cm* (47.49[P])

Checkup	*1[st]*	*2[nd]*
Photograph		
Scanned Signatures	*ME*	*ME*
Class	IV	IV
Date of Checkup (*year-month-day*)	2011-05-22	2011-11-13
Age (*year-month-day*)	08-07-29	09-01-20
Age (*decimal year*)	8.66	9.14
Dress Code	0/0.5	0/0.5
Behavior Code	0	0
Height, *h* (*cm*)	129.50[£]	131.00[£]
Height (*ft-in*)	4 *ft* 2.98 *in*	4 *ft* 3.57 *in*
Percentile-for-Height, *P*(*h*)	39.73[£]	34.33[£]
Estimated-Adult Height (*cm*)	161.54	160.60
Estimated-Adult Height (*ft–in*)	**5 *ft* 3.60 *in***	**5 *ft* 3.23 *in***
Current-Age-Mid-Parental (MP) Height (*cm*)	130.76	133.20
Δ Height *w. r. t.* Current-Age-MP Height (*cm*)	–1.26	–2.20
Algebraic Status (pertaining-to-height), $STATUS_{\pm}(h)$	–0.96%	+1.65%
Qualitative Status (pertaining-to-height)	**Normal**	**1[st]-Deg Stunted**
Current-Age-Army-Cutoff Height (*cm*)	125.78	128.06
Δ Height *w. r. t.* Army-Cutoff Height (*cm*)	+3.72	+2.94
Reference Height (*cm*)[∀]	130.76	133.20
Percentile-for-Reference-Height, P_{ref}[Σ]	47.49	47.49
Gross Mass (*kg*)	31.90	31.79
Clothing Correction (*kg*)	0	0
Net Mass, μ (*kg*)	31.90	31.79
Net Weight (*lb-oz*)	70 *lb* 5.43 *oz*	70 *lb* 1.55 *oz*
Percentile-for-Net-Mass, $P(\mu)$	75.79	63.42
Estimated-Adult Mass (*kg*)	66.35	62.32
Estimated-Adult Weight (*lb–oz*)	146 *lb* 4.86 *oz*	137 *lb* 6.54 *oz*
Height-Percentile-based-Optimal Mass, μ_{opt} (*kg*)	26.57	27.45
Δ Mass-for-Height (*kg*)	+5.33	+4.34
Algebraic Status (pertaining-to-mass), $STATUS_{\pm}(\mu)$	+20.08%	+15.82%
Qualitative Status (pertaining-to-mass)	**3[rd]-Deg Obese**	**2[nd]-Deg Obese**
Percentile-for-*BMI*-based-Optimal-Mass, $P(\mu_{\text{BMI}})$	64.46	62.05
BMI-based-Optimal-Mass, μ_{BMI} (*kg*)	30.03	31.56
Estimated-Adult *BMI* (kg/m^2)	25.43	24.16
Nutritional Status	**EC II**[⊆]	**EC II**
$P(h) + P(\mu)$	115.51	97.76
Build	**Medium**	**Medium**

[§]The superscript P stands for *percentile*.
[£]Pseudo-gain of height (Kamal *et al*., 2014*b*) exhibited between 1[st] and 2[nd] checkups (height pick up from 129.50 *cm* to 131.00 *cm*, percentile dropping from 39.72 to 34.74).
[∀]Reference height is taken as the maximum of measured height, current-age-mid-parental height and current-age-army-cutoff height.
[Σ]Percentile-for-reference-height is the maximum value selected from percentiles of measured height, mid-parental height and army-cutoff height.
[⊆]Energy-Channelization II (Kamal *et al*., 2014*b*)

Table A1*b*. Month-wise-targets determined using Growth-and-Obesity Vector-Roadmap for M. E. based on her most-recent checkup

Target Date	*Height Target*		*Mass Target*	
	cm	*ft-in*	*kg*	*lb-oz*
December 13, 2011	131.80	4 *ft* 3.89 *in*	31.64	69 *lb* 12.26 *oz*
January 13, 2012	132.59	4 *ft* 4.32 *in*	31.52	69 *lb* 8.03 *oz*
February 13, 2012	133.33	4 *ft* 4.49 *in*	31.44	69 *lb* 5.20 *oz*
March 13, 2012	134.00	4 *ft* 4.76 *in*	31.40[¥]	69 *lb* 3.79 *oz*
April 13, 2012	134.66	4 *ft* 5.02 *in*	31.42[¥]	69 *lb* 4.50 *oz*
May 13, 2012	135.29	4 *ft* 5.26 *in*	31.49[¥]	69 *lb* 6.97 *oz*

[¥] 4^{th}- and 5^{th}-*month* as well as 5^{th}- and 6^{th}-*month* recommendations exhibit pseudo-gain of mass (Kamal *et al*., 2014*b*) — in the first case there is a mass gain from 31.40 *kg* to 31.42 *kg* with percentile drop from 53.52 to 51.75, whereas in the second case there is a mass gain from 31.42 *kg* to 31.49 *kg* with percentile drop from 51.75 to 50.32.

APPENDIX A: GROWTH-AND-OBESITY VECTOR-ROADMAPS OF POSSIBLE CANDIDATES

Dress code and behavior code are explained in Kamal *et al*. (2002) and Kamal (2006). As all children were weighed wearing panties only, their 'net masses' were assumed to be equal to 'gross masses' (clothing correction negligible).

Case 1**:** M. E. (SGPP-KHI-20100421-03/01) — This is the case $P(h, A_0) < P_{\text{ref}} \bullet P(\mu, A_0) > P_{\text{ref}}$, illustrated in Tables A1*a*, *b*.

Case 2**:** Q. H. (NGDS-BLA-2010-4657/Z) — This is the case $P(h, A_0) = P_{\text{ref}} \bullet P(\mu, A_0) > P_{\text{ref}}$, illustrated in Tables A2*a*, *b*.

Case 3**:** Z. I. R. (SGPP-KHI-20100908-01/04) — This is the case $P(h, A_0) < P_{\text{ref}} \bullet P(\mu, A_0) = P_{\text{ref}}$, illustrated in Tables A3*a*, *b*.

Case 4**:** Z. H. Z. (SGPP-KHI-20110412-01/01; NGDS-BLA-2010-5484/Z) — This case illustrated in Tables A4*a*, *b*, representing the conditions, $P(h, A_0) = P_{\text{ref}} \bullet P(\mu, A_0) < P_{\text{ref}} \bullet P(\mu, A_0) > P(h, A_0)$. History and clinical photographs of this case appear in Kamal (2015*a*).

Case 5**:** Z. J. (SGPP-KHI-20100908-01/04) — This is the case $P(h, A_0) < P_{\text{ref}} \bullet P(\mu, A_0) = P_{\text{ref}}$, illustrated in Tables A5*a*, *b*.

APPENDIX B: ADDITIONAL RESOURCES

Additional File 1 (http://www.ngds-ku.org/Papers/J45/Additional_File_1.pdf) contains description of institutional review process, description of the NGDS checkups and SGPP checkups as well as virtual tour of the SF-Growth-and-Imaging Laboratory.

Additional File 2 (http://www.ngds-ku.org/Papers/J45/Additional_File_2.pdf) contains detailed calculations of Growth-and-Obesity Vector-Roadmap of case 1**:** M. E. (SGPP-KHI-20100421-03/01)

Additional File 3 (http://www.ngds-ku.org/Papers/J45/Additional_File_3.pdf) displays graphs of navigational and guidance trajectories and recommended control action for cases 1-5 included in the main document. In addition, this file lists RGB values of all the colors used in Growth-and-Obesity Vector-Roadmap.

APPENDIX C: COMPLIANCE WITH ETHICAL STANDARDS

*Conflict of Interest***:** The authors declare that they don't have any financial/non-financial competing interests in the research presented in this work.

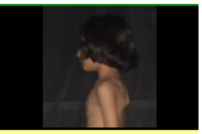
*Institutional Review***:** The NGDS Pilot Project was initiated in 1998 under of directives of Governor Sindh/Chancellor, University of Karachi after proper institutional review process. The project was designed after considering North American and European, ethical and human-right standards. Additional File 1 gives the details.

*Informed Consent***:** 'The Informed Consent Form' for school studies, based on opt-in policy is included in Additional File 1 and is, also, available at**:** http://www.ngds-ku.org/ngds_folder/Protocols/NGDS_form.pdf. 'The SGPP Participation Form' for detailed checkups in the SF-Growth-and-Imaging Laboratory is, also, part of Additional File 1. In addition, it is uploaded at**:** http://www.ngds-ku.org/SGPP/SGPP_form.pdf. Both forms required signatures of father and mother as well as their child(ren). Before the start of checkup, verbal permission was sought from the child(ren) and the attending parent(s).

*Privacy, Confidentiality, Comfort and Safety***:** Both visual as well as acoustic privacy is offered in the SF-Growth-and-Imaging Laboratory. Family labels and children's initials presented in this manuscript and the supplementary documents

Table A2*a*. Growth-and-Obesity Vector-Roadmap of Q. H. (NGDS-BLA-2010-4657/Z)

Gender: Female ♀ • *Date of Birth* (*year-month-day*): 2006-01-12 • *Army-Cutoff Height*: 157.48 *cm* (19.36[P])
Father's Height: ♂ 166.56 *cm* • *Mother's Height*: ♀ 156.63 *cm* • *Target Height*: 155.10 *cm* (10.29[P])

Checkup	*1st*	*2nd*	*3rd*
Photograph			
Scanned Signatures	*QH*	*QH*	QH
Class	KG	I	II
Date of Checkup (*year-month-day*)	2011-05-04	2012-03-19	2013-06-12
Age (*year-month-day*)	05-03-22	06-02-07	07-05-00
Age (*decimal year*)	5.31	6.18	7.41
Dress Code	0/0.5	0/0.5	0/0.5
Behavior Code	0	0	0
Height, h (*cm*)	110.30¶	114.92¶	122.25¶
Height (*ft-in*)	3 *ft* 7.43 *in*	3 *ft* 9.24 *in*	4 *ft* 0.13 *in*
Percentile-for-Height, $P(h)$	53.51¶	42.36¶	37.69¶
Estimated-Adult Height (*cm*)	163.95	162.00	161.18
Estimated-Adult Height (*ft–in*)	**5 *ft* 4.55 *in***	**5 *ft* 3.78 *in***	**5 *ft* 3.46 *in***
Current-Age-Mid-Parental (MP) Height (*cm*)	103.82	109.57	117.15
Δ Height *w. r. t.* Current-Age-MP Height (*cm*)	+6.48	+5.35	+5.10
Algebraic Status (pertaining-to-height), $STATUS_{\pm}(h)$	+6.24%	+4.88%	+4.36%
Qualitative Status (pertaining-to-height)	**1st-Deg Tall**	**1st-Deg Tall**	**1st-Deg Tall**
Current-Age-Army-Cutoff Height (*cm*)	105.53	111.39	119.12
Δ Height *w. r. t.* Army-Cutoff Height (*cm*)	+4.77	+3.53	+3.13
Reference Height (*cm*)	110.30	114.92	122.25
Percentile-for-Reference-Height, P_{ref}	53.51	42.36	37.69
Gross Mass (*kg*)	23.30	25.32	23.45
Clothing Correction (*kg*)	0	0	0
Net Mass, $\mu(kg)$	23.30¢	25.32¢	23.45
Net Weight (*lb-oz*)	51 *lb* 6.02 *oz*	55 *lb* 13.29 *oz*	51 *lb* 11.32 *oz*
Percentile-for-Net-Mass, $P(\mu)$	90.93¢	87.07¢	45.23
Estimated-Adult Mass (*kg*)	76.76	73.49	57.12
Estimated-Adult Weight (*lb–oz*)	169 *lb* 4.19 *oz*	162 *lb* 0.85 *oz*	125 *lb* 15.32 *oz*
Height-Percentile-based-Optimal Mass, μ_{opt} (*kg*)	18.91	20.11	22.74
Δ Mass-for-Height (*kg*)	+4.39	+5.21	+0.71
Algebraic Status (pertaining-to-mass), $STATUS_{\pm}(\mu)$	+23.22%	+25.91%	+3.13%
Qualitative Status (pertaining-to-mass)	**3rd-Deg Obese**	**3rd-Deg Obese**	**1st-Deg Obese**
Percentile-for-*BMI*-based-Optimal-Mass, $P(\mu_{BMI})$	70.61	65.61	63.54
BMI-based-Optimal-Mass, μ_{BMI} (*kg*)	20.30	22.17	25.54
Estimated-Adult *BMI* (kg/m^2)	28.56	28.00	21.99
Nutritional Status	**ON®**	**ON**	**ON**
$P(h) + P(\mu)$	144.44	129.43	82.92
Build	**Medium**	**Medium**	**Medium**

¶Pseudo-gain of height exhibited between 1st and 2nd checkups (height pick up from 110.30 *cm* to 114.92 *cm*, percentile dropping from 53.51 to 42.36) as well as between 2nd and 3rd checkups (height pick up from 114.92 *cm* to 122.25 *cm*, percentile dropping from 42.36 to 37.69).
¢Pseudo-gain of mass exhibited between 1st and 2nd checkups (mass put on from 23.30 *kg* to 25.32 *kg*, percentile dropping from 90.93 to 87.07).
®Over-Nutrition (Kamal *et al*., 2014*b*)

Table A2*b*. Month-wise-targets determined using Growth-and-Obesity Vector-Roadmap for Q. H. based on her most-recent checkup

Target Date	*Height Target*		*Mass Target*	
	cm	*ft-in*	*kg*	*lb-oz*
July 12, 2013	122.76	4 *ft* 0.33 *in*	23.63	52 *lb* 1.67 *oz*
August 12, 2013	123.25	4 *ft* 0.52 *in*	23.82	52 *lb* 8.37 *oz*
September 12, 2013	123.74	4 *ft* 0.72 *in*	24.02	52 *lb* 15.43 *oz*
October 12, 2013	124.22	4 *ft* 0.91 *in*	24.21	53 *lb* 6.13 *oz*
November 12, 2013	124.71	4 *ft* 1.10 *in*	24.41	53 *lb* 13.18 *oz*
December 12, 2013	125.18	4 *ft* 1.28 *in*	24.60	54 *lb* 3.89 *oz*

do not correspond to first letters in actual names (as per confidentiality standards established by the NGDS Team). Same is true about case numbers appearing in the main and the additional material. Comfort of patients is of prime concern. Although, both parents are invited to the checkups to share history and progress, same-gender parent is preferred to be present at the actual checkup in the curtained-off area for maximum comfort of the child. Prior to checkups, school-checkup-room floor was cleaned to remove sharp objects on floor. Benches/chairs were checked for sharp wood edges as well as both sides of the mounted engineering tape to prevent skin abrasions and cuts. In SF-Growth-and-Imaging Laboratory, the entire floor is black-tiled, street shoes are not allowed for anyone, floor mopped with dettol (chloro-xylenol)-mixed water. Thermometer bulbs, when not in use, remain dipped in dettol-mixed water. Hand washing/sanitization is mandatory at the beginning of each checkup. Health professionals and anthropometrists are required to remove hand-worn chains, rings and wristwatches to prevent injury to examinees.

*Disclosure and regret Model***:** Adapted from University of Michigan Health System's Disclosure, Apology and Offer Model (Simmons, 2016), in which any mistake in report is notified to the parents with regrets; mother, accompanied by father, are requested to come and discuss the report with the principal investigator (author of this paper).

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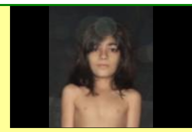
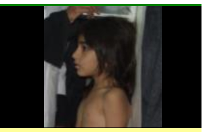
Table A3*a*. Growth-and-Obesity Vector-Roadmap of Z. I. R. (SGPP-KHI-20100908-01/04)

Gender: Female • *Date of Birth* (*year-month-day*): 2004-03-29 • *Army-Cutoff Height*: 157.48 *cm* (19.36[P])
Father's Height: 164.02 *cm* • *Mother's Height*: 151.12 *cm* • *Target Height*: 151.07 *cm* (2.98[P])

Checkup	*1st*	*2nd*
Photograph		
Scanned Signatures	*ZIR*	*ZIR*
Class	II	II
Date of Checkup (*year-month-day*)	2011-10-09	2012-01-08
Age (*year-month-day*)	07-06-10	07-09-09
Age (*decimal year*)	7.53	7.78
Dress Code	0/0.5	0/0.5
Behavior Code	0	0
Height, *h* (*cm*)	115.81[$]	117.13[$]
Height (*ft-in*)	3 *ft* 9.59 *in*	3 *ft* 10.11 *in*
Percentile-for-Height, *P*(*h*)	4.97[$]	4.96[$]
Estimated-Adult Height (*cm*)	152.63	152.62
Estimated-Adult Height (*ft–in*)	**5 *ft* 0.09 *in***	**5 *ft* 0.09 *in***
Current-Age-Mid-Parental (MP) Height (*cm*)	114.60	115.91
Δ Height *w. r. t.* Current-Age-MP Height (*cm*)	+1.21	+1.22
Algebraic Status (pertaining-to-height), $STATUS_{\pm}(h)$	+1.05%	+1.06%
Qualitative Status (pertaining-to-height)	**1st-Deg Tall**	**1st-Deg Tall**
Current-Age-Army-Cutoff Height (*cm*)	119.80	121.19
Δ Height *w. r. t.* Army-Cutoff Height (*cm*)	-3.99	–4.06
Reference Height (*cm*)	119.80	121.19
Percentile-for-Reference-Height, P_{ref}	19.36	19.36
Gross Mass (*kg*)	20.90	21.56
Clothing Correction (*kg*)	0	0
Net Mass, μ (*kg*)	20.90	21.56
Net Weight (*lb-oz*)	46 *lb* 1.35 *oz*	47 *lb* 8.64 *oz*
Percentile-for-Net-Mass, $P(\mu)$	17.20	19.36[⊕]
Estimated-Adult Mass (*kg*)	50.35	50.54
Estimated-Adult Weight (*lb–oz*)	111 *lb* 0.30 *oz*	111 *lb* 6.99 *oz*
Height-Percentile-based-Optimal Mass, μ_{opt} (*kg*)	19.13	19.62
Δ Mass-for-Height (*kg*)	+1.77	+1.94
Algebraic Status (pertaining-to-mass), $STATUS_{\pm}(\mu)$	+9.23%	+9.90%
Qualitative Status (pertaining-to-mass)	**1st-Deg Obese**	**1st-Deg Obese**
Percentile-for-*BMI*-based-Optimal-Mass, $P(\mu_{BMI})$	39.94	39.91
BMI-based-Optimal-Mass, μ_{BMI} (*kg*)	23.26	23.95
Estimated-Adult *BMI* (kg/m^2)	21.61	21.70
Nutritional Status	**ON**	**ON**
$P(h) + P(\mu)$	22.17	22.85
Build	**Small**	**Small**

[$]Pseudo-gain of height exhibited between 1st and 2nd checkups (height pick up from 115.81 *cm* to 117.13 *cm*, percentile dropping from 4.97 to 4.96).
[⊕]Mass percentile for the second checkup comes out to 17.89. However, 19.36 is used in place of 17.89 to illustrate the case in which mass percentile of the most-recent checkup matches with the reference percentile (Kamal *et al*., 2016*a*).

Table A3*b*. Month-wise-targets determined using Growth-and-Obesity Vector-Roadmap for Z. I. R. based on her most-recent checkup

Target Date	*Height Target*		*Mass Target*	
	cm	*ft-in*	*kg*	*lb-oz*
February 8, 2012	118.01	3 *ft* 10.46 *in*	21.94	48 *lb* 6.04 *oz*
March 8, 2012	118.82	3 *ft* 10.78 *in*	22.12	48 *lb* 12.39 *oz*
April 8, 2012	119.65	3 *ft* 11.11 *in*	22.33	49 *lb* 3.80 *oz*
May 8, 2012	120.43	3 *ft* 11.41 *in*	22.54	49 *lb* 11.21 *oz*
June 8, 2012	121.22	3 *ft* 11.72 *in*	22.75	50 *lb* 2.62 *oz*
July 8, 2012	121.86	3 *ft* 11.98 *in*	22.96	50 *lb* 10.03 *oz*

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Table A4*a*. Growth-and-Obesity Vector-Roadmap of Z. H. Z.
(SGPP-KHI-20110412-01/01; NGDS-BLA-2010-5484/A) — Part I

Gender: Female • *Date of Birth* (*year-month-day*): 2005-06-16 • *Army-Cutoff Height*: 157.48 *cm* (19.36^P)
Father's Height: 178.20 *cm* • *Mother's Height*: 170.78 *cm* • *Target Height*: 167.99 *cm* (76.12^P)

Checkup	*1*st	*2*nd	*3*rd
Photograph			
Scanned Signatures	*ZHZ*	*ZHZ*	*ZHZ*
Class	KG	I	I
Date of Checkup (*year-month-day*)	2011-05-04	2012-03-20	2012-05-13
Age (*year-month-day*)	05-10-18	06-09-04	06-10-27
Age (*decimal year*)	5.88	6.76	6.91
Dress Code	0/0.5	0/0.5	0/0.5
Behavior Code	0	0	0
Height, *h* (*cm*)	113.40	119.42	120.45
Height (*ft-in*)	3 *ft* 8.65 *in*	3 *ft* 11.02 *in*	3 *ft* 11.42 *in*
Percentile-for-Height, *P*(*h*)	46.42	46.65	47.02
Estimated-Adult Height (*cm*)	162.71	162.75	162.82
Estimated-Adult Height (*ft–in*)	**5 *ft* 4.06 *in***	**5 *ft* 4.08 *in***	**5 *ft* 4.10 *in***
Current-Age-Mid-Parental (MP) Height (*cm*)	117.64	123.90	124.92
Δ Height *w. r. t.* Current-Age-MP Height (*cm*)	–4.24	–4.48	–4.47
Algebraic Status (pertaining-to-height), $STATUS_{\pm}(h)$	–3.60%	–3.61%	–3.58%
Qualitative Status (pertaining-to-height)	**1st-Deg Stunted**	**1st-Deg Stunted**	**1st-Deg Stunted**
Current-Age-Army-Cutoff Height (*cm*)	109.45	115.19	116.12
Δ Height *w. r. t.* Army-Cutoff Height (*cm*)	+3.95	+4.23	+4.33
Reference Height (*cm*)	117.64	123.90	124.92
Percentile-for-Reference-Height, P_{ref}	76.12	76.12	76.12
Gross Mass (*kg*)	18.30	20.14	20.74
Clothing Correction (*kg*)	0	0	0
Net Mass, μ (*kg*)	18.30$^{\Delta}$	20.14$^{\Delta}$	20.74
Net Weight (*lb-oz*)	40 *lb* 5.62 *oz*	44 *lb* 6.54 *oz*	45 *lb* 11.71 *oz*
Percentile-for-Net-Mass, $P(\mu)$	26.81$^{\Delta}$	26.09$^{\Delta}$	29.25
Estimated-Adult Mass (*kg*)	52.89	52.73	53.45
Estimated-Adult Weight (*lb–oz*)	116 *lb* 10.08 *oz*	116 *lb* 4.26 *oz*	117 *lb* 13.89 *oz*
Height-Percentile-based-Optimal Mass, μ_{opt} (*kg*)	19.70	21.86	22.26
Δ Mass-for-Height (*kg*)	–1.40	–1.72	–1.52
Algebraic Status (pertaining-to-mass), $STATUS_{\pm}(\mu)$	–7.12%	–7.86%	–6.85%
Qualitative Status (pertaining-to-mass)	**1st-Deg Wasted**	**1st-Deg Wasted**	**1st-Deg Wasted**
Percentile-for-*BMI*-based-Optimal-Mass, $P(\mu_{BMI})$	67.43	67.53	67.70
BMI-based-Optimal-Mass, μ_{BMI} (*kg*)	21.54	24.01	24.46
Estimated-Adult *BMI* (kg/m^2)	19.98	19.91	20.16
Nutritional Status	**UN$^{\Downarrow}$**	**UN**	**UN**
$P(h) + P(\mu)$	73.23	72.72	76.27
Build	**Medium**	**Medium**	**Medium**

$^{\Delta}$Pseudo-gain of mass exhibited between 1st and 2nd checkups (mass gain from 18.30 *kg* to 20.14 *kg*, percentile dropping from 26.81 to 26.07).
$^{\Downarrow}$Under-Nutrition (Kamal *et al*., 2014*b*)

Table A4*b*. Growth-and-Obesity Vector-Roadmap of Z. H. Z.
(SGPP-KHI-20110412-01/01; NGDS-BLA-2010-5484/A) — Part II

Gender: Female • *Date of Birth* (*year-month-day*): 2005-06-16 • *Army-Cutoff Height*: 157.48 *cm* (19.36^{P})
Father's Height: 178.20 *cm* • *Mother's Height*: 170.78 *cm* • *Target Height*: 167.99 *cm* (76.12^{P})

Checkup	4^{th}	5^{th}
Photograph		
Scanned Signatures	*ZHZ*	*ZHZ*
Class	II	IV
Date of Checkup (*year-month-day*)	2013-06-02	2014-11-21
Age (*year-month-day*)	07-11-16	09-05-07
Age (*decimal year*)	7.96	9.44
Dress Code	0/0.5	0/0.5
Behavior Code	0	0
Height, *h* (*cm*)	117.84$^{\Omega}$	136.56
Height (*ft-in*)	3 *ft* 10.39 *in*	4 *ft* 5.76 *in*
Percentile-for-Height, *P*(*h*)	4.54	58.22
Estimated-Adult Height (*cm*)	152.30	164.77
Estimated-Adult Height (*ft–in*)	**4 *ft* 11.96 *in***	**5 *ft* 4.87 *in***
Current-Age-Mid-Parental (MP) Height (*cm*)	131.65	139.81
Δ Height *w. r. t.* Current-Age-MP Height (*cm*)	–13.81	–3.25
Algebraic Status (pertaining-to-height), $STATUS_{\pm}(h)$	–10.49%	–2.32%
Qualitative Status (pertaining-to-height)	**2nd-Deg Stunted**	**1st-Deg Stunted**
Current-Age-Army-Cutoff Height (*cm*)	122.27	129.51
Δ Height *w. r. t.* Army-Cutoff Height (*cm*)	–4.43	+7.05
Reference Height (*cm*)	131.65	139.81
Percentile-for-Reference-Height, P_{ref}	76.12	76.12
Gross Mass (*kg*)	25.12	33.06
Clothing Correction (*kg*)	0	0
Net Mass, μ(*kg*)	25.12	33.06
Net Weight (*lb-oz*)	55 *lb* 6.23 *oz*	72 *lb* 14.36 *oz*
Percentile-for-Net-Mass, $P(\mu)$	46.25	63.50
Estimated-Adult Mass (*kg*)	57.36	62.34
Estimated-Adult Weight (*lb–oz*)	126 *lb* 7.56 *oz*	137 *lb* 7.37 *oz*
Height-Percentile-based-Optimal Mass, μ_{opt} (*kg*)	19.85	32.12
Δ Mass-for-Height (*kg*)	+5.27	+0.94
Algebraic Status (pertaining-to-mass), $STATUS_{\pm}(\mu)$	+26.54%	+2.94%
Qualitative Status (pertaining-to-mass)	**3rd-Deg Obese**	**1st-Deg Obese**
Percentile-for-*BMI*-based-Optimal-Mass, $P(\mu_{\text{BMI}})$	38.89	72.73
BMI-based-Optimal-Mass, μ_{BMI} (*kg*)	24.35	34.71
Estimated-Adult *BMI* (kg/m^2)	24.73	22.96
Nutritional Status	**EC II**	**EC II**
$P(h) + P(\mu)$	50.79	121.10
Build	**Medium**	**Medium**

$^{\Omega}$This sharp drop in height seems to be a measurement error.

Table A4*c*. Month-wise-targets determined using Growth-and-Obesity Vector-Roadmap for Z. H. Z. based on her most-recent checkup

Target Date	*Height Target*		*Mass Target*	
	cm	*ft-in*	*kg*	*lb-oz*
December 23, 2014	137.38	4 *ft* 6.09 *in*	33.53	73 *lb* 15.05 *oz*
January 23, 2015	139.04	4 *ft* 6.74 *in*	34.88	76 *lb* 14.55 *oz*
February 23, 2015	140.10	4 *ft* 7.16 *in*	35.76	78 *lb* 13.62 *oz*
March 23, 2015	140.96	4 *ft* 7.50 *in*	36.47	80 *lb* 6.53 *oz*
April 23, 2015	141.74	4 *ft* 7.80 *in*	37.55	82 *lb* 12.82 *oz*
May 23, 2015	142.45	4 *ft* 8.08 *in*	38.25	84 *lb* 5.32 *oz*

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Table A5*a*. Growth-and-Obesity Vector-Roadmap of Z. J. (SGPP-KHI-20060412-01/01)

Gender: Female • *Date of Birth* (*year-month-day*): 1996-09-23 • *Army-Cutoff Height*: 157.48 *cm* (19.36[P])
Father's Height: 165.70 *cm* • *Mother's Height*: 155.73 *cm* • *Target Height*: 154.22 *cm* (8.31[P])

Checkup	*1st*	*2nd*	*3rd*
Photograph			
Scanned Signatures	*ZJ*	*ZJ*	*ZJ*
Class	V	VI	VI
Date of Checkup (*year-month-day*)	2007-05-13	2007-10-07	2008-06-15
Age (*year-month-day*)	10-07-20	11-00-14	11-08-22
Age (*decimal year*)	10.63	11.04	11.73
Dress Code	0/0.5	0/0.5	0/0.5
Behavior Code	0	0	0
Height, *h* (*cm*)	136.41	139.70	146.53
Height (*ft-in*)	4 *ft* 5.71 *in*	4 *ft* 7.00 *in*	4 *ft* 9.69 *in*
Percentile-for-Height, $P(h)$	23.18	26.76	36.69
Estimated-Adult Height (*cm*)	158.49	159.27	161.01
Estimated-Adult Height (*ft–in*)	**5 *ft* 2.40 *in***	**5 *ft* 2.71 *in***	**5 *ft* 3.39 *in***
Current-Age-Mid-Parental (MP) Height (*cm*)	131.88	134.11	138.74
Δ Height *w. r. t.* Current-Age-MP Height (*cm*)	+4.53	+5.59	+7.79
Algebraic Status (pertaining-to-height), $STATUS_{\pm}(h)$	+3.43%	+4.17%	+5.61%
Qualitative Status (pertaining-to-height)	**1st-Deg Tall**	**1st-Deg Tall**	**1st-Deg Tall**
Current-Age-Army-Cutoff Height (*cm*)	135.42	137.80	142.57
Δ Height *w. r. t.* Army-Cutoff Height (*cm*)	+0.99	+1.90	+3.96
Reference Height (*cm*)	136.41	139.70	146.53
Percentile-for-Reference-Height, P_{ref}	23.18	26.76	36.69
Gross Mass (*kg*)	42.50	46.50	49.60
Clothing Correction (*kg*)	0	0	0
Net Mass, μ (*kg*)	42.50	46.50[Ø]	49.60[Ø]
Net Weight (*lb-oz*)	93 *lb* 11.40 *oz*	102 *lb* 8.52 *oz*	109 *lb* 5.89 *oz*
Percentile-for-Net-Mass, $P(\mu)$	78.36	82.41[Ø]	80.85[Ø]
Estimated-Adult Mass (*kg*)	67.98	70.54	69.56
Estimated-Adult Weight (*lb–oz*)	149 *lb* 14.41 *oz*	102 *lb* 8.52 *oz*	153 *lb* 5.97 *oz*
Height-Percentile-based-Optimal Mass, μ_{opt} (*kg*)	30.94	33.16	37.82
Δ Mass-for-Height (*kg*)	+11.56	+13.34	+11.78
Algebraic Status (pertaining-to-mass), $STATUS_{\pm}(\mu)$	+37.35%	+40.24%	+31.16%
Qualitative Status (pertaining-to-mass)	**4nh-Deg Obese**	**4th-Deg Obese**	**4th-Deg Obese**
Percentile-for-*BMI*-based-Optimal-Mass, $P(\mu_{BMI})$	56.76	58.72	62.88
BMI-based-Optimal-Mass, μ_{BMI} (*kg*)	37.08	39.39	43.68
Estimated-Adult *BMI* (kg/m^2)	27.07	27.81	26.83
Nutritional Status	**ON**	**ON**	**ON**
$P(h) + P(\mu)$	101.54	109.17	117.54
Build	**Medium**	**Medium**	**Medium**

[Ø]Pseudo-gain of mass exhibited between 2nd and 3rd checkups (mass put on from 46.50 *kg* to 49.60 *kg*, percentile dropping from 82.41 to 80.85).

Table A5*b*. Month-wise-targets determined using Growth-and-Obesity Vector-Roadmap for Z. J. based on her most-recent checkup

Target Date	*Height Target*		*Mass Target*	
	cm	*ft-in*	*kg*	*lb-oz*
July 15, 2008	147.12	4 *ft* 9.91 *in*	47.98	105 *lb* 12.73 *oz*
August 15, 2008	147.71	4 *ft* 10.15 *in*	46.36	102 *lb* 3.58 *oz*
September 15, 2008	148.29	4 *ft* 10.39 *in*	44.74	98 *lb* 10.43 *oz*
October 15, 2008	148.88	4 *ft* 10.62 *in*	43.12	95 *lb* 1.27 *oz*
November 15, 2008	149.47	4 *ft* 10.85 *in*	41.50	91 *lb* 8.12 *oz*
December 15, 2008	150.06	4 *ft* 11.08 *in*	39.88	87 *lb* 14.97 *oz*

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