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# VALIDATION OF CONCEPT OF OPTIMAL MASS IN CHILDREN AND ADULTS — THE SEVENTH-GENERATION SOLUTION OF CHILDHOOD OBESITY[η]

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## ABSTRACT

Childhood obesity being a result of difference between intake and expenditure of energy, disturbing initial steady state and forming a new steady state at a higher level, resulting in increased body-fat storage. To avoid obesity, child needs to balance tissue synthesis, responsible for picking-up height, with fat storage, responsible for putting-on weight (mass). During 2002-2012, child growth and obesity were modeled, introducing the terms, estimated-adult *BMI*, pseudo-gain of height/mass and energy-channelization (co-existence of wasting and tallness/stunting and obesity). During 2013-2017, our group put forward first- to sixth-generation solutions of childhood obesity, which included new a definition of childhood obesity. This paper unveils seventh-generation solution, placing height-percentile-based-optimal mass and *BMI*-based-optimal mass on equal footing by defining modified status (pertaining-to-mass) in terms of that optimal mass, which is closer to net mass. Similarly, current-age-mid-parental height and current-age-army-cutoff height are treated on equal footing by defining modified status (pertaining-to-height) in terms of that current-age height, which is closer to recorded height. This leads to a modification of definitions of 'instantaneous obesity/wasting' and 'true obesity/wasting'. Polar-coördinate representation of nutritional-status classification is expanded to 10 categories, viz. energy-channelization III (puberty-induced energy-channelization), obesity dominated over-nutrition, tallness dominated over-nutrition, tallness dominated energy-channelization I, wasting dominated energy-channelization I, stunting dominated energy-channelization II, obesity dominated energy-channelization II, stunting dominated under-nutrition, wasting dominated under-nutrition, acute malnutrition. Growth-and-Obesity Vector-Roadmap 2.1 includes 'away-from-normality index' and 'polar angle' in addition to build assigned from scaled percentiles, modified as well as descriptive statuses (pertaining-to-height) and (pertaining-to-mass). Vector-Roadmap 2.1 proposes a range for 6 monthly height-management-target values and 6 monthly mass-management-target ranges. Target ranges, instead of single values, render the task of optimal-mass management easier. In this work, lifestyle adjustment, diet and exercise plans have been expanded to achieve the recommended targets. Vector-Roadmap 2.1 is generated from height and mass measurements to least counts of 0.005 *cm* and 0.005 *kg*, respectively. Computations are performed using Extended CDC Growth Charts and Tables containing percentiles in the range 0.01 to 99.99. In the appendices, true obesity implying instantaneous obesity and instantaneous wasting implying true wasting are proved using rigorous mathematical arguments, with illustrative examples for each condition.

**Keywords:** Height-percentile-based-optimal mass, *BMI*-based-optimal mass, instantaneous obesity, instantaneous wasting, true obesity, true wasting, expanded nutritional status

## LIST OF ABBREVIATIONS

**AC:** **A**rmy-**C**utoff (in the context of height)
**AM:** **A**cute **M**alnutrition
***BMI*:** **B**ody-**M**ass **I**ndex
**CA:** **C**urrent-**A**ge (in the context of height)
**CDC:** **C**enters for **D**isease **C**ontrol and Prevention
**EC I-III:** **E**nergy-**C**hannelization I-III
**ECOG:** **E**uropean **C**hildhood **O**besity **G**roup
**IU:** **I**nternational **U**nit (dosage of vitamin D)
**MP:** **M**id-**P**arental (in the context of height)
**NGDS:** **N**ational **G**rowth and **D**evelopmental **S**tandards for the Pakistani Children
**ON:** **O**ver-**N**utrition
**P:** **P**ercentile
**SGPP:** **S**ibling **G**rowth **P**ilot **P**roject — a subproject of the NGDS Pilot Project
**UN:** **U**nder-**N**utrition
**UV:** **U**ltra**v**iolet (in the context of sunlight radiation)
**WHO:** **W**orld **H**ealth **O**rganization

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**Units:** *cm***:** centimeter(s) • *ft***:** foot (feet) • *g***:** gram(s) • *in***:** inch(es) • *kg***:** kilogram(s) • *l***:** liter(s) • *lb***:** pound(s) • *m***:** meter(s) • *ml***:** milliliter(s) • *oz***:** ounce(s) • $\mu g$**:** microgram(s)

**Conversion Factors:** 1 *ft* = 12 *in* • 1 $g = 10^6\ \mu g$ • 1 *in* = 2.54 *cm* • 1 $kg = 10^3\ g$ • 1 *kg* = 2.205 *lb* • 1 $l = 10^3\ ml$ • 1 *lb* = 16 *oz* • 1 $m = 10^2\ cm$

## INTRODUCTION

Childhood obesity, being the outcome of a complex web of biological, cultural, environmental and psychological influences, has become a universal problem. The severe complications, which occur due to childhood obesity, affect cardiovascular, gastrointestinal, musculoskeletal, neurologic, psychosocial, pulmonary and renal systems. One must be quick to realize that childhood is a key period of life for shaping of health habits. Hence, this is definitely the ideal period to detect childhood obesity so that appropriate planning is done to initiate efficient and effective intervention strategies.

In this paper, concept of optimal mass is validated to generate 7$^{th}$-generation solution of childhood obesity. Height-percentile-based-optimal mass and *BMI*-based-optimal-mass have been integrated and definition of status (pertaining-to-mass) is modified to treat both of the above optimal masses on equal footing. During this exercise, polar-coördinate representation has been worked out, which provides ‘away-from-normality index’ and ‘polar angle’. Nutritional-status has now been classified into 10 categories instead of 6 categories being used since 2015.

## CHILDHOOD OBESITY: SOCIO-ECONOMIC DETERMINANTS AND TRENDS

Wickramasinghe (2018) proposed a conceptual framework at the individual level, at the family level, at the community level and at the policy-making level, to understand the environmental as well as the socio-cultural factors, which influence occurrence of obesity in youngsters. The child was portrayed at the center of a socio-ecological model with culture and society at the outermost periphery, followed by government/industry, community, school and peers as well as family and home. Holmgren *et al.* (2017) have investigated relationship of pubertal height gain and peak body-mass index in childhood. Saldaña-Tejeda (2018) discussed mother’s experiences of masculinity in the context of child obesity in Mexico.

Kato *et al.* (2018) have investigated earlier *BMI* rebound and lower pre-*BMI* rebound as obesity risk among Japanese preschool children. Jaarsveld and Gulliford (2014) have investigated childhood-obesity trends in England and concluded that the prevalence of overweight and obesity might have stabilized between 2004 and 2013. Ogden *et al.* (2014; 2016) have investigated childhood, adolescent and adult obesity in United States during the periods 1998-2004, 2011-2012 and 2013-2014. Skinner and Skelton (2014) investigated prevalence and trends in obesity and severe obesity among children in the United States, 1999-2012. Hardy *et al.* (2017) have investigated 30-year trends in overweight, obesity and waist-to-height ratio by socioeconomic status in Australian children, 1985 to 2015.

## CHILDHOOD OBESITY: DEFINITIONS

The key to childhood-obesity management is agreeing on a definition of obesity. Realizing that obesity occurs, when there discrepancy between energy input and output. The original steady state vanishes and a new one appears at a higher level. The consequence is increased body-fat storage (Wabitsch, 2000). Poskitt (1995), on behalf of the European Childhood Obesity Group (ECOG), observed that researchers were worried about a lack of definition of childhood obesity. She introduced relative *BMI* as the index of a 50$^{th}$ *centile* youngster. *BMI* (computed using the expression $\mu / h^2$ — $\mu$ representing mass in *kg* and *h* height in *m*) was renamed as body-mass index from the Quetelet index 46 *years* ago (Keys *et al.*, 1972). In a follow-up work, Poskitt (2000) stated that there is a considerable imprecision in defining obesity. However, there seems to be a general acceptance of the concept of relative *BMI*. In a 2001 paper, she was of the opinion that *BMI* does not offer the ‘best’ definition, although it may be regarded as the most ‘useful’ and ‘practical’ one for clinical, epidemiological and population-research purposes (Poskitt, 2001). Kolotourou *et al.* (2013) asked the question if *BMI* alone was a suitable indicator to decide about interventions for childhood obesity, concluding that setting a *BMI*-reduction cutoff might be misleading, other competing outcomes should be considered. Cole *et al.* (2000) gave a definition of childhood obesity based on pooled-international data. They connected childhood obesity to adult-obesity-cutoff point of *BMI* to be 30 $kg/m^2$. Flegal *et al.* (2010) classified *BMI*-for-age as ‘normal’, ‘intermediate’ and ‘high’. On behalf of ECOG, Rolland-Cachera (2011), gave 4 ranges for main cutoffs of *BMI* distribution status from the age of 5 *years***:** ‘thin’, ‘normal’, ‘overweight’ (not obese) and ‘obese’. Skinner and Skelton (2014) defined overweight and obesity in children on the

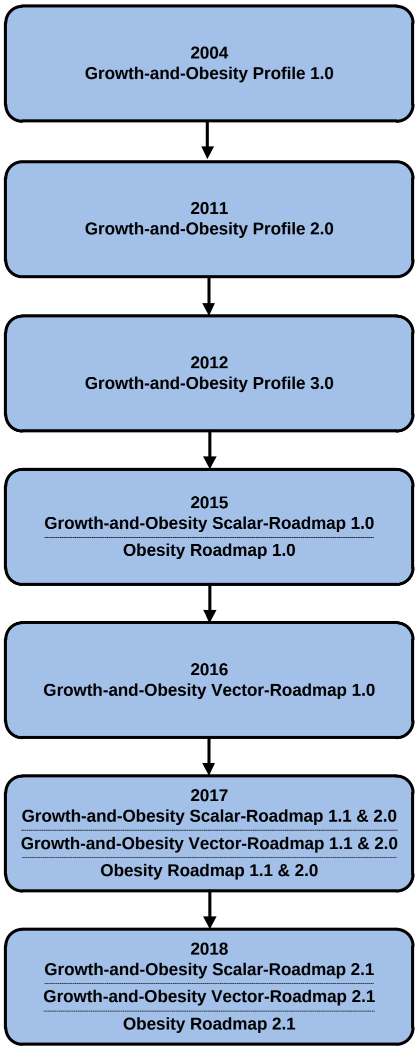



Fig. 1. Timeline of modeling of child growth and obesity

basis of percentiles of *BMI* — above 85th percentile**:** overweight; above 95th percentile**:** obese. Last year, Flegal and Ioannidis (2017) published an evaluation of the Global *BMI* Mortality Collaboration.

The first author streamlined various definitions of childhood obesity and put forward 'logical definition' (Kamal, 2016*b*). Last year, a 'mathematical definition' was given (Kamal, 2017*b*). The mathematical definition was validated using anthropometric data collected during 1998-2013 (Kamal *et al*., 2017*a*).

## CHILDHOOD OBESITY: MODELS

Whitaker *et al*. (1997) presented a statistical model to predict obesity in adolescence from parental and childhood obesity. Golan and Weizman (2001) proposed a family-centered model for childhood-obesity management. Change is brought upon through Parents are convinced to adopt a healthy lifestyle to bring about the change through role modeling (Natale *et al*., 2014) and not losing mass. This becomes possible only when there is a will to bring about the change (Meldrum *et al*., 2017). Kumar and Kelly (2018) reviewed childhood obesity from epidemiological and etiological perspectives as well as the associated comorbidities. They discussed various methods of clinical assessment and treatment.

Figure 1 illustrates timeline of modeling of childhood-obesity problem by our group. The major challenge in constructing such a mathematical model are the realities that the youngster, under optimal conditions, who is picking up height with the passage of time as well as putting on (shedding off) mass. If an obese child is required to reduce mass, based on status of current obesity, in the absence of rigorous calculation of height to be gained within the next few months, the youngster could become wasted (lesser mass-for-height). Hence, it becomes very important to account for the trend of height gain by youngster in various phases of growth — infancy, childhood and puberty (Figure 2). Our group attempted to take this into consideration,

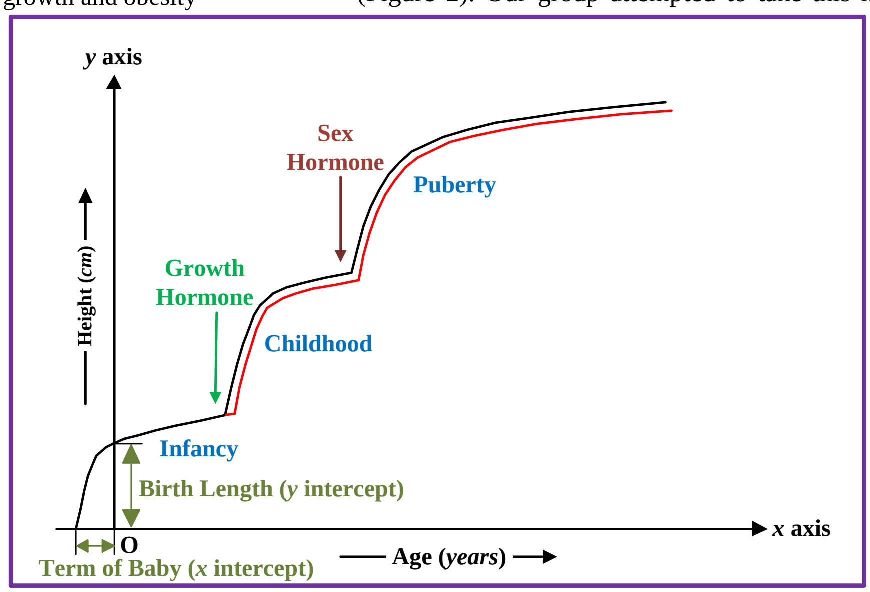



Fig. 2. ICP model**:** Mathematical interpretation (Karlberg, 1987) — Children suffering from severe disease (*e. g*., diarrhea) during the weaning period may continue on the infancy curve a little longer, before picking up the childhood curve and, hence, end up stunted (the red path)

when constructing models of childhood obesity. The childhood-obesity models developed by our group are listed below**:**

***Growth-and-Obesity Profiles***

'Growth-and-Obesity Profiles 1.0', also known as KFA (Kamal-Firdous-Alam) model, compute growth and obesity statuses of child after at least 2 checkups and provide growth (height) velocity as well as rate of mass (weight) gain/loss between these checkups (Kamal *et al.*, 2004).

'Growth-and-Obesity Profiles 2.0', also known as KJK (Kamal-Jamil-Khan) model, provide of 'Obesity Profiles 2.0' of parents (also, all adults aged 20 *years* or more) as well as growth and obesity statuses of each child based on only one single check up, growth velocity and rate of mass gain not possible to compute (Jamil, 2009; Kamal *et al.*, 2011).

'Growth-and-Obesity Profiles 3.0', also known as KJ (Kamal-Jamil) model, extend version 2.0 to account for still-growing parents — mothers below 19 *years* and fathers below 21 *years* (Jamil, 2014; Kamal and Jamil, 2012). This model determines target height of a child by replacing heights of biological mother and father with their respective estimated-adult heights in the formulae.

'CDC Growth Charts and Tables' are extrapolated to include extreme percentiles (range 0.01 to 99.99) in the KJ-Regression model (Kamal and Jamil, 2014).

***Growth-and-Obesity Roadmaps***

'Growth-and-Obesity Scalar-Roadmaps 1.0' (Ansari, 2015; Kamal *et al.*, 2015) are generalization 'Growth-and-Obesity Moving-Profiles' (Kamal *et al.*, 2014*b*), which include 6 month-wise recommendations to gain/lose mass for parents ('Obesity Roadmaps 1.0') as well as manage heights and masses for sons and daughters through 6 monthly recommendations (Kamal, 2015*a*; *b*), assign build (Kamal and Khan, 2015; Kamal *et al.*, 2017*b*) and classify nutritional status (Kamal, 2014; 2015*a*; Kamal *et al.*, 2014*b*; 2017*a*; *b*). Scalar-Roadmaps 1.0 alert pediatrician to pseudo-gain of mass (height), whenever present (Kamal *et al.*, 2014*b*) — mass (height) gain with a drop on CDC-percentile trajectory. Examples are available in Additional File of Kamal (2014).

'Growth-and-Obesity Vector-Roadmaps 1.0' (Naz, 2017; Kamal *et al.*, 2016*a*) are identical to 'Growth-and-Obesity Scalar-Roadmaps 1.0' in the range of actual checkups. Prime difference is in assigning 6 monthly targets for height and mass management, computed by fitting parabolic trajectories for CDC height and mass percentiles. These softer targets propose to achieve corrections by the end-of-childhood phase, instead of a short span of 6 *months*.

'Growth-and-Obesity Profiles 1.0' (Kamal *et al.*, 2004) are only of academic value, 'Growth-and-Obesity Profiles 2.0' (Kamal *et al.*, 2011) are used to generate 'Growth-and-Obesity Scalar-Roadmaps 1.0', 'Obesity Roadmaps 1.0' (Kamal *et al.*, 2013*d*; 2014*a*; 2015), 'Growth-and-Obesity Scalar-Roadmaps 1.1', 'Obesity Roadmaps 1.1' (Kamal *et al.*, 2017*b*; *c*) as well as 'Growth-and-Obesity Vector-Roadmaps 1.0' (Kamal *et al.*, 2016*a*; *b*) and 'Growth-and-Obesity Vector-Roadmaps 1.1' (2017*b*; *c*). Roadmaps 1.1 are different from their respective versions 1.0, mainly, in the introduction of scaled percentiles to compute build and severity of acute malnutrition (if present).

'Growth-and-Obesity Profiles 2.0' are used in constructing 'Growth-and-Obesity Scalar-Roadmaps 2.0' and 'Growth-and-Obesity Vector-Roadmaps 2.0'. For parents 'Obesity Roadmaps 1.0' are generalized to 'Obesity Roadmaps 2.0'. These roadmaps provide ranges of 6 monthly mass-management targets instead of single values, which are more realistic to achieve.

Perry *et al.* (2018) have reported short-term and long-term behavior outcomes in a 6-*month* family-based weight management program.

## CHILDHOOD OBESITY: SOLUTIONS

No single most important intervention is available for treatment of childhood obesity (Rutter, 2012). However, family-based community interventions have been attempted (Fagg *et al.*, 2014; Perry *et al.*, 2018). Mother's perception of her child's obesity problem (Berggren *et al.*, 2018) and community beliefs (Covic *et al.*, 2007) do matter the outcome of any intervention program. Greydanus *et al.* (2018) elaborate concepts of obesity in children and adolescents in the earlier part of this century, including reflections on its history, definition, epidemiology, diagnostic perspectives, psychological considerations, muculoskeletal as well as endocrine complications and principles of management. Zylke and Buchner (2018) have discussed prevention strategies to overcome childhood obesity. Parkinson *et al.* (2017) have introduced the food system compass to encourage balanced eating, which may result in controlling childhood obesity.

Various groups have proposed solutions of childhood-obesity problem. Poskitt (2005) opines that treatment focusing on increasing consumption of energy and decreasing intake of energy seldom show long-lasting effects. Robinson and Sirard (2005) put forward solution-oriented research paradigm for avoiding childhood obesity, which

| | |
|---|---|
| September 4, 2013 | 1st-Generation Solution of Childhood Obesity (Kamal *et al*., 2013*d*) |
| 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*b*) |
| February 13, 2016 | 4th-Generation Solution of Childhood Obesity (Kamal *et al*., 2016*b*) |
| January 1, 2017 | 5th-Generation Solution of Childhood Obesity (Kamal, 2017*a*) |
| October 1, 2017 | 6th-Generation Solution of Childhood Obesity (Kamal, 2017*b*) |
| October 1, 2018 | 7th-Generation Solution of Childhood Obesity (this work) |

Fig. 3. Solutions of childhood-obesity problem proposed by the NGDS Team — photograph of child's mass being recorded, first appeared in Kamal and Jamil (2012), published in the same journal

encouraged child-health-related research. Mazik *et al.* (2007) suggested understanding the bigger picture of childhood obesity by looking the wider determinants of obesity, such as walking-biking-friendly neighborhood, social interactions, food marketing and pricing. Wieting (2008) studied cause and effect in childhood obesity to uncover a solution. Finegood *et al.* (2010) looked into implications of the Foresight Obesity System Map.

Mathematical-statistical techniques were used by the NGDS Team (NGDS stands for 'National Growth and Developmental Standards for the Pakistani Children' http://ngds-ku.org) during 2013-2017 to propose $1^{st}$- to $6^{th}$-generation solutions of childhood obesity. $1^{st}$- to $3^{rd}$-generation solutions were summarized in Kamal (2015*c*). In this paper, $7^{th}$ generation solution is put forward (Figure 3).

## CHILDHOOD OBESITY: MONITORING

Anthropometric measures commonly employed for monitoring of childhood obesity are standing height (stature), mass (weight), waist circumference and hip circumference. Some of the anthropometric and non-anthropmetric measures are described in Kamal and Jamil (2014) — expanded version is available in Figures 4*a*-*c*. Field and laboratory studies conducted by the NGDS Team are described below**:**

### *Field Study — the NGDS Pilot Project*

The NGDS Pilot Project was initiated in 1998 under the directives of Governor Sindh, after following 'Institutional Review Process'— project designed after considering applicable ethical and human-right protocols (Kamal *et al*., 2002), described in detail in Additional File 1 of Kamal (2017*c*).

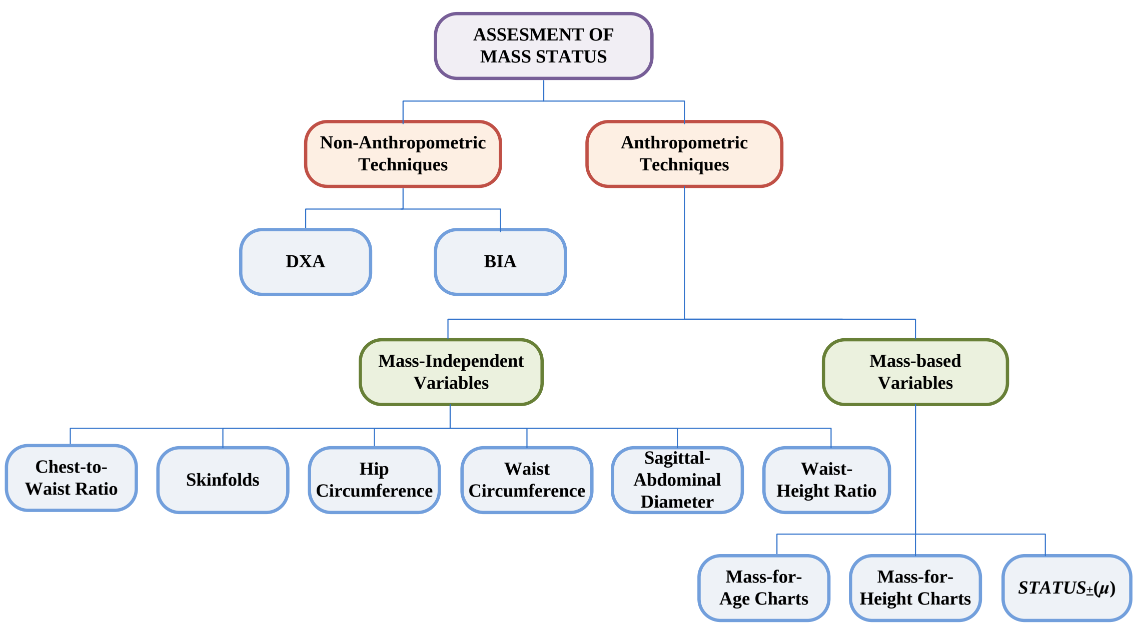



Fig. 4*a*. Classification of methods available for assessment of mass status combined

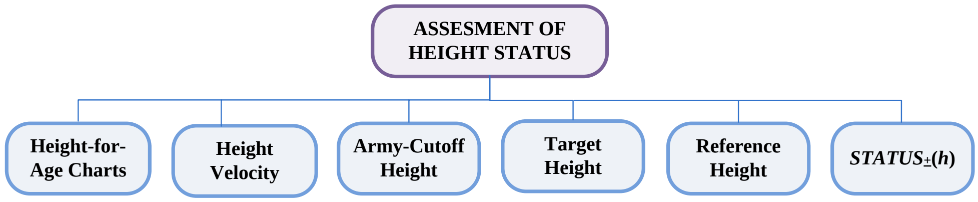



Fig. 4*b*. Classification of methods available for assessment of height status combined

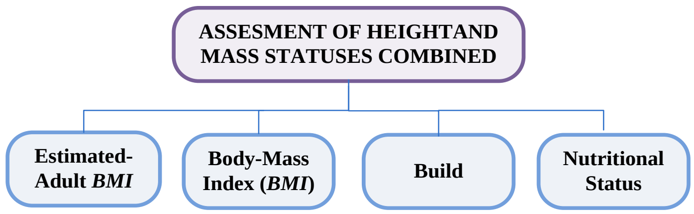



Fig. 4*c*. Classification of methods available for assessment of height and mass statuses combined

Four representative schools (1 civilian and 3 operated by the Armed Forces of Pakistan**:** Pakistan Army; Pakistan Navy; Pakistan Air Force) were chosen for conduct of the NGDS Pilot Project, participation was based on 'opt-in' policy; only those pupils were measured whose parents signed the consent slip, part of 'Informed Consent Form' http://www.ngds-ku.org/ngds_folder/Protocols/NGDS_Form.pdf — A dedicated room, furnished according to examination needs, having acoustic as well as visual privacy for gender-segregated unclothed checkups, was provided by each school authority.

***Laboratory Study — Sibling Growth Pilot Project***

SGPP (Sibling Growth Pilot Project) http://www.ngds-ku.org/ngds_URL/subprojects.htm#SGPP was a family-centered subproject, which monitored health of enrolled families, who visited Growth-and-Imaging Laboratory for checkups along with their 5-10-*year*-old sons and daughters. The lab was maintained germ-free by forbidding outside shoes/flip-flops for youngsters, their parents as well as staff of laboratory. Floor was black tiled and mopped with dettol-mixed water prior to each session (generic name of dettol is chloroxylenol). For enrolment, the parents signed 'SGPP Participation Form', which included complete information and illustrations of procedures http://www.ngds-ku.org/SGPP/SGPP_Form.pdf

Checkups were conducted giving due regard to parents' and children's' comfort, confidentiality, dignity, privacy and safety.

***Techniques of Height and Mass Measurement — Least Counts*: *0.005 cm and 0.005 kg***

The key to childhood-obesity research is obtaining accurate height and weight measurements (Gobte and Meyer, 2018). Heights, *h*, and masses, $\mu$, were measured by reproducible anthropometrists (Figures 5*a*, *b*), according to laid-down protocols (Kamal *et al.*, 2013*e*) given in the official manual (Kamal, 2016*a*). Additional File 2 of Kamal (2017*c*) gives the abbreviated version with step-by-step procedures explained through labeled photographs. A series of 5 educational videos have been prepared to further reinforce methods of taking anthropometric measurements (Kamal, 2017*a*). Heights were measured to least counts of 0.1 *cm* (1998-2011, setsquare set — Kamal and Firdous, 2002*a*; *b*); 0.01 *cm* (2012-2015, Vernier scale — Kamal, 2010) and 0.005 *cm* (2016 to date, enhanced-Vernier scale

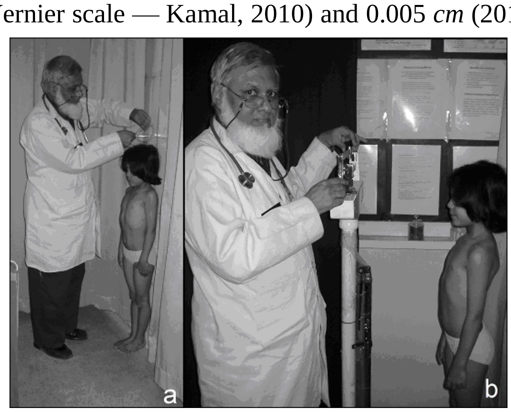


Fig. 5*a*, *b*. Measurements of (*a*) height and (*b*) mass of a girl; the second author assisted in anthropometry of this child — photographs first appeared in Kamal *et al.* (2014*b*), published in the same journal

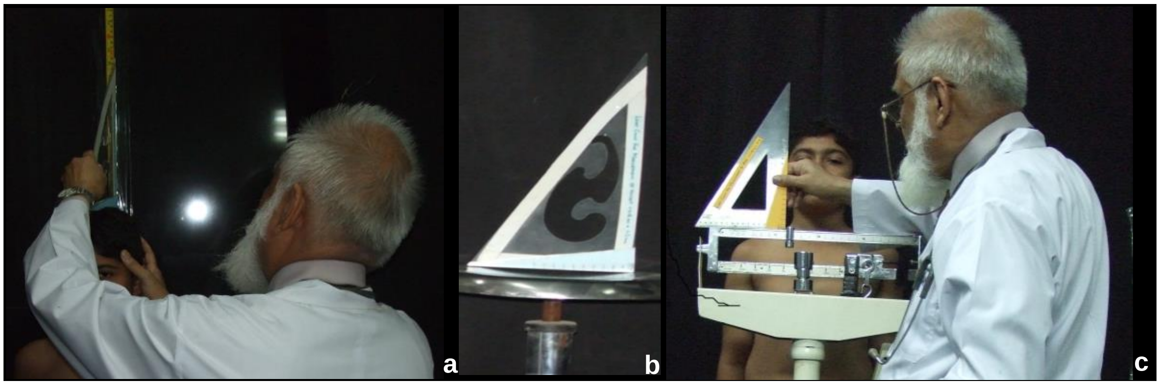



Fig. 6*a*, *b*. Close up of setsquare set for measurements of (*a*, *b*) height and (*c*) mass of a boy to least counts of 0.005 *cm* and 0.005 *kg*, respectively

— Kamal *et al.*, 2016*b*). Masses were recorded to least counts of 0.5 *kg* (1998-2011, bathroom scale— Kamal and Firdous, 2002*a*; *b*); 0.01 *kg* (2012-2015, modified-beam scale — Kamal, 2010) and 0.005 *kg* (2016-present, enhanced-beam scale — Kamal *et al.*, 2016*b*) before noon, with the children barefoot and totally stripped except briefs or panties (Figures 6*a*, *b*). At the start of each daily session, measuring instruments were calibrated, zero errors noted and subtracted from measured values. Disrobing to short underpants enabled the measurers to ascertain that the child maintained upright posture (knees and elbows not flexed, toes and heels not lifted, Frankfort plane parallel to ground, feet apart for mass measurement/feet together for height measurement) and complete inhaling.

## GROWTH-AND-OBESITY VECTOR-ROADMAP 2.1

For the purpose of the following discussion, age range, $A$, for different phases of growth are**:** the earlier-childhood period (generally prepubertal**:** child not yet entering puberty) — $A < 9.5\, years$; the later-childhood period (generally peripubertal**:** youngsters about to enter puberty, characterized by leveling off of height trajectory) — $9.5\, years \le A < 12\, years$; the transition period (generally pubertal**:** incumbent in the process of entering puberty, characterized by energy-channelization III, puberty-induced energy-channelization; height gain almost ceases, mass and fat gains, in particular below the waist) — $12\, years \le A < 13.5\, years$; the adolescence period — $13.5\, years \le A < 20\, years$; the adulthood period — $A \ge 20\, years$ (Kamal *et al.*, 2017*b*). Energy-channelization III was introduced in Kamal (2014) and explained in Kamal *et al.* (2016*c*).

### *Version* 2.1— *the Need*

Growth-and-Obesity Vector-Roadmap 1.0 (Kamal *et al.*, 2016*a*; *b*) was supposed to assign softer targets for mass and height management as the targets proposed in Scalar-Roadmap 1.0 (Kamal *et al.*, 2015) were thought to be too demanding as they tried to achieve the entire correction within a short span of 6 *months*. Growth-and-Obesity Vector-Roadmap 2.0 (Kamal, 2017*b*) proposed a range instead of a single value for mass management. However, this formulation was biased towards height-percentile-based-optimal mass, as status (pertaining-to-mass) was computed using this optimal mass. In order to have an unbiased interpretation of both height-percentile-based- and *BMI*-based-optimal masses (defined in the section on 'Growth-and-Obesity Profiles 2.1' appearing below), we are modifying the definition of status (pertaining-to- mass).

### *Version* 2.1— *Method for Generating*

*Condition of Applicability***:** Growth-and-Obesity Vector-Roadmap 2.1 applies to youngsters, who have both parents in the adulthood period.

*Behavior Code***:** Behavior code has 3 possible values**:** 0 (coöperative and relaxed — ideal for measurements); 1 (shy and timid, but cooperative — measurements permissible); 2 (nagging and a resistant — measurements not reliable)

*Dress Code***:** Dress code was recorded with the findings (quantitative or descriptive) as a fraction, numerator (denominator) describing amount of clothing superior (inferior) to transverse plane containing the naval. A value 0/0.5 (recommended for measurements of youngsters) meant that the child was measured barefoot and completely undressed except under-shorts. Behavior and dress codes code are described in Kamal (2016*a*) and Kamal *et al.* (2002).

*CDC Growth Charts and Tables (extended version)*: These charts and tables list masses and heights of females and males in the extended range of CDC percentiles, 0.01-99.99 (Kamal and Jamil, 2014).

*Scaled Growth Charts and Tables* (*for the Pakistani population*): Height and mass scaled percentiles, to be used for the Pakistani population, were obtained from CDC percentiles by fitting a parabolic curve to each percentile such that 40th CDC percentile corresponds to 50th scaled percentile (Kamal *et al.*, 2017*b*).

(1*a*, *b*) $$P_{\text{Scaled}}(h) = \frac{17P_{\text{CDC}}(h)}{12} - \frac{P_{\text{CDC}}^2(h)}{240};\; P_{\text{Scaled}}(\mu) = \frac{17P_{\text{CDC}}(\mu)}{12} - \frac{P_{\text{CDC}}^2(\mu)}{240}$$

*Growth-and-Obesity Profiles 2.1* (*for the periods of childhood, transition and adolescence*): CDC percentiles of cutoff heights for induction into the Armed Forces of Pakistan, $P_{\text{AC}}$ (Kamal *et al.*, 2017*c*), as well as target height, also called 'mid-parental percentile', $P_{\text{MP}}$ (Tanner *et al.*, 1970), were evaluated using age-20-height values obtained from Extended CDC Growth Tables using the technique of 'linear interpolation'. For the Pakistani boys, army-cutoff height, $h_{\text{AC}}$, is 62.56 *cm* (5 *ft* 4 *in*), $P_{\text{AC}}$ comes out to 2.718014592103645…, for girls $h_{\text{AC}}$ is 157.48 *cm* (5 *ft* 2 *in*), the corresponding percentile is 19.35609323536863…. $P_{\text{MP}}$ is the CDC percentile corresponding to gender-specific-adult-mid-parental (target) height (in *cm*) given by $h_{\text{MP}} = \frac{h_{\text{F}} + h_{\text{M}}}{2} \pm 6.5\,cm$, where $h_{\text{F}}$ and $h_{\text{M}}$ were heights of father and mother measured in *cm*; positive sign taken for male child's target height; negative sign for female child's target height. 'Box interpolation' (Kamal *et al.*, 2011) was employed to determine child's CDC percentiles of height, $P_{\text{CDC}}(h, A)$, and mass, $P_{\text{CDC}}(\mu, A)$. 'Linear interpolation' was utilized to compute estimated-adult height (mass), $h_{\text{est-adult}}$ ($\mu_{\text{est-adult}}$), using these percentiles and age-20 values as well as evaluate estimated-adult *BMI* (Kamal and Jamil, 2012), $\frac{\mu_{\text{est-adult}}}{h^2_{\text{est-adult}}}$, (mass in kg; height in *m*). Constant-age route was utilized to evaluate 'height-percentile-based-optimal mass', $\mu_{\text{opt}}$, mass corresponding to CDC percentile of height (Kamal *et al.*, 2004; 2011). '*BMI*-based-Optimal Mass', $\mu_{\text{BMI}}$, for a youngster was computed in 3 steps: (*i*) 'Estimated-Adult-*BMI*-based-Optimal Mass' was evaluated using the expression $\mu_{\text{BMI-est-adult}} = 24h^2_{\text{est-adult}}$ (estimated-adult height in *m*), (*ii*) 'CDC Percentile for *BMI*-based-Optimal Mass', $P_{\text{CDC}}(\mu_{\text{BMI}}, A)$, was evaluated using linear interpolation to estimated-adult-*BMI*-based-optimal mass, $\mu_{\text{BMI-est-adult}}$, (*iii*) box interpolation (Kamal *et al.*, 2011) was used to evaluate '*BMI*-based-Optimal Mass' at the given age. Similar procedure was employed to estimate current-age-mid-parental height, $h_{\text{CA-MP}}$, and current-age-army-cutoff height, $h_{\text{CA-AC}}$.

Algebraic status (pertaining-to-height), $STATUS_{\pm}(\mu)$, and algebraic status (pertaining-to-mass), $STATUS_{\pm}(h)$, employed in Growth-and Obesity Vector-Roadmap 2.0 are, now, replaced by modified status (pertaining-to-height), $STATUS_{\pm}^{\text{MOD}}(h)$, and modified status (pertaining-to-mass), $STATUS_{\pm}^{\text{MOD}}(\mu)$, respectively.

In $STATUS_{\pm}^{\text{MOD}}(h)$ range of normality is extended, stunting and tallness are redefined based on closeness of measured height to $h_{\text{CA-MP}}$ and $h_{\text{CA-AC}}$ (Table 1). Figure 7*a* represents concept of stunting and tallness in the form of number line. Descriptive status (pertaining-to-height) now replaces qualitative status (pertaining-to-height) and assigned as per recipe given in Figure 7*b*. Fractional status (pertaining-to-height), $STATUS_{Fr}(h)$, is obtained as

(2*a*) $$STATUS_{Fr}(h) = \frac{STATUS_{\pm}^{\text{MOD}}(h)}{100}$$

Table 1. Mathematical expressions of modified status (pertaining-to-height)$^{\lambda}$

| *Mathematical Condition* | *Mathematical Expression of* $STATUS_{\pm}^{\text{MOD}}(h)$ | *Qualitative Description* |
|---|---|---|
| $h < h_{\text{min}}$ | $100\,\frac{h - h_{\text{min}}}{h_{\text{min}}}\,\% < 0$ | Stunted |
| $h_{\text{min}} \le h \le h_{\text{max}}$ | 0 | Normal |
| $h > h_{\text{max}}$ | $100\,\frac{h - h_{\text{max}}}{h_{\text{max}}}\,\% > 0$ | Tall |

$^{\lambda} h_{min} = min\,(h_{\text{CA-MP}}, h_{\text{CA-AC}}),\; h_{max} = max\,(h_{\text{CA-MP}}, h_{\text{CA-AC}})$

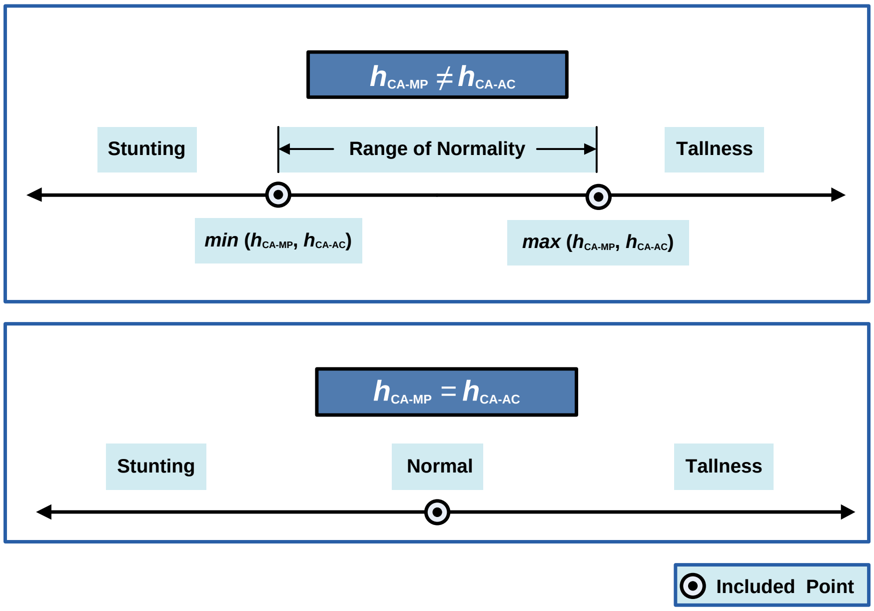



Fig. 7*a*. Number-line representation of current-age-mid-parental height and current-age-army-cutoff height

| | |
|---|---|
| 4th-Degree Stunted | $STATUS_{\pm}^{MOD}(h) < -30\%$ |
| 3rd-Degree Stunted | $-30\% \leq STATUS_{\pm}^{MOD}(h) < -20\%$ |
| 2nd-Degree Stunted | $-20\% \leq STATUS_{\pm}^{MOD}(h) < -10\%$ |
| 1st-Degree Stunted | $-10\% \leq STATUS_{\pm}^{MOD}(h) < 0$ |
| Normal | $STATUS_{\pm}^{MOD}(h) = 0$ |
| 1st-Degree Tall | $0\% < STATUS_{\pm}^{MOD}(h) < +10\%$ |
| 2nd-Degree Tall | $+10\% \leq STATUS_{\pm}^{MOD}(h) < +20\%$ |
| 3rd-Degree Tall | $+20\% \leq STATUS_{\pm}^{MOD}(h) < +30\%$ |
| 4th-Degree Tall | $STATUS_{\pm}^{MOD}(h) \geq +30\%$ |

Fig. 7*b*. Color codes used to represent descriptive status (pertaining-to-height)

In $STATUS_{\pm}^{MOD}(\mu)$, range of normality is extended, wasting and obesity are redefined based on closeness of net mass (mass obtained without any clothing worn; for children weighed in short underpants, stripped-to-waist, measured mass is very close to net mass and no clothing correction is applied) to $\mu_{\text{opt-corrected}}$ and $\mu_{\text{BMI-corrected}}$—corrected masses are obtained by adding 5 *kg* to computed optimal masses of females, who are about to be married/ married/recently divorced/recently widowed to accommodate for possible pregnancy and the associated fetal mass (Table 2). Figure 8*a* represents concept of wasting and obesity in the form of number line. Descriptive status (pertaining-to-mass) now replaces qualitative status (pertaining-to-mass) and assigned as per recipe given in Figure 8*b*. Fractional status (pertaining-to-mass), $STATUS_{Fr}(\mu)$, is obtained as

$$STATUS_{Fr}(\mu) = \frac{STATUS_{\pm}^{MOD}(\mu)}{100} \qquad (2b)$$

Table 2. Mathematical expressions of modified status (pertaining-to-mass)[ξ]

| *Mathematical Condition* | *Mathematical Expression of* $STATUS_{\pm}^{MOD}(\mu)$ | *Qualitative Description* |
|---|---|---|
| $\mu < \mu_{min}$ | $100\,\frac{\mu - \mu_{min}}{\mu_{min}}\,\% < 0$ | Wasted |
| $\mu_{min} \le \mu \le \mu_{max}$ | 0 | Normal |
| $\mu > \mu_{max}$ | $100\,\frac{\mu - \mu_{max}}{\mu_{max}}\,\% > 0$ | Obese |

[ξ] $\mu_{min} = min\,(\mu_{opt\text{-}corrected}, \mu_{BMI\text{-}corrected})$, $\mu_{max} = max\,(\mu_{opt\text{-}corrected}, \mu_{BMI\text{-}corrected})$

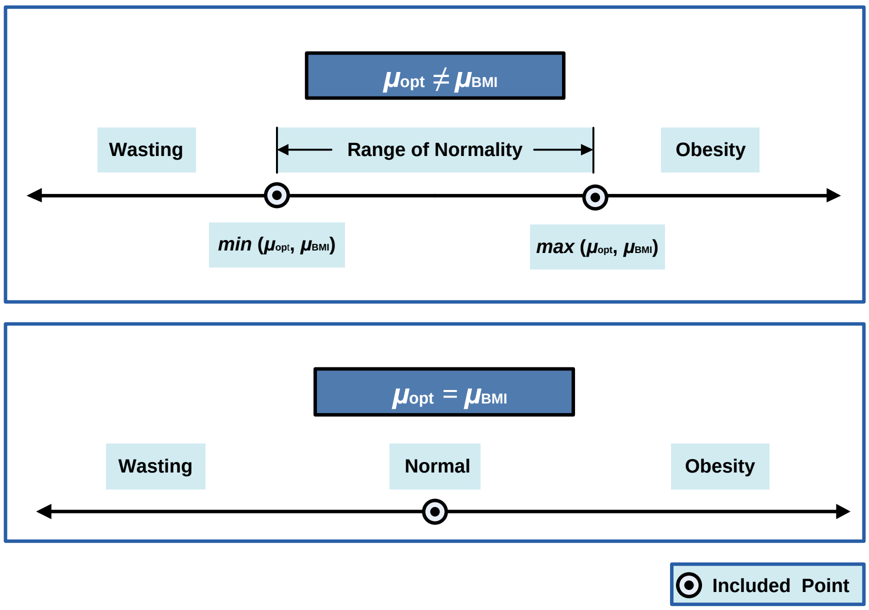



Fig. 8*a*. Number-line representation of height-percentile-based-optimal mass and *BMI*-based-optimal mass

| | |
|---|---|
| 4th-Degree Wasted | $STATUS_{\pm}^{MOD}(\mu) < -30\%$ |
| 3rd-Degree Wasted | $-30\% \le STATUS_{\pm}^{MOD}(\mu) < -20\%$ |
| 2nd-Degree Wasted | $-20\% \le STATUS_{\pm}^{MOD}(\mu) < -10\%$ |
| 1st-Degree Wasted | $-10\% \le STATUS_{\pm}^{MOD}(\mu) < 0$ |
| Normal | $STATUS_{\pm}^{MOD}(\mu) = 0$ |
| 1st-Degree Obese | $0\% < STATUS_{\pm}^{MOD}(\mu) < +10\%$ |
| 2nd-Degree Obese | $+10\% \le STATUS_{\pm}^{MOD}(\mu) < +20\%$ |
| 3rd-Degree Obese | $+20\% \le STATUS_{\pm}^{MOD}(\mu) < +30\%$ |
| 4th-Degree Obese | $STATUS_{\pm}^{MOD}(\mu) \ge +30\%$ |

Fig. 8*b*. Color codes used to represent descriptive status (pertaining-to-mass)

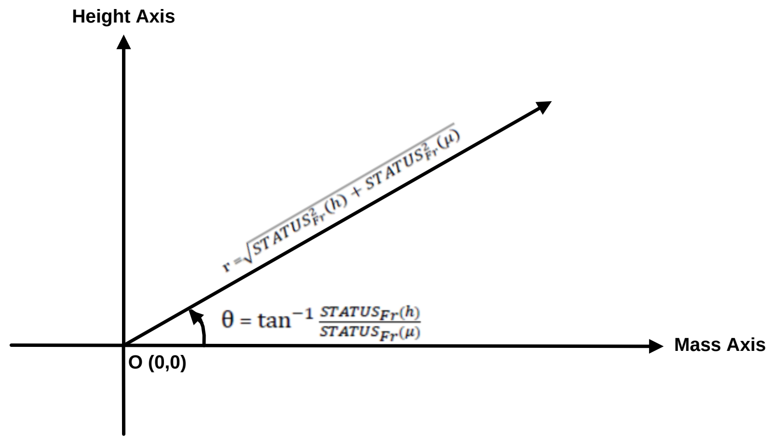



Fig. 9. Polar-coördinate interpretation of fractional statuses, pertaining-to-height and pertaining-to-mass

Fractional status (pertaining-to-height-and-mass), $STATUS_{Fr}(\hbar)$, may be represented as a complex number. We include below a little mathematics of complex-number representation as this paper is intended for audiences in biological sciences, who do not have a solid background in mathematics. A complex number, $z$, having a real part, $x$, and an imaginary part, $y$, may be expressed in terms of $r$ and $\theta$ ($i = \sqrt{-1}$)

(3) $$z = x + iy = r(\cos\theta + i\sin\theta) \Rightarrow r = \sqrt{x^2 + y^2}, \theta = \tan^{-1}\frac{y}{x}$$

$r$ in our case is termed as 'away-from-normality index'. Equation (3), therefore, becomes (Figure 9)

$$STATUS_{Fr}(\hbar) = STATUS_{Fr}(\mu) + iSTATUS_{Fr}(h) \Rightarrow r = \sqrt{STATUS_{Fr}^2(\mu) + STATUS_{Fr}^2(h)}, \theta = \tan^{-1}\frac{STATUS_{Fr}(h)}{STATUS_{Fr}(\mu)}$$

Figure 10 illustrates expanded classification of nutritional statuses. Polar-angle range both in degrees and in radians

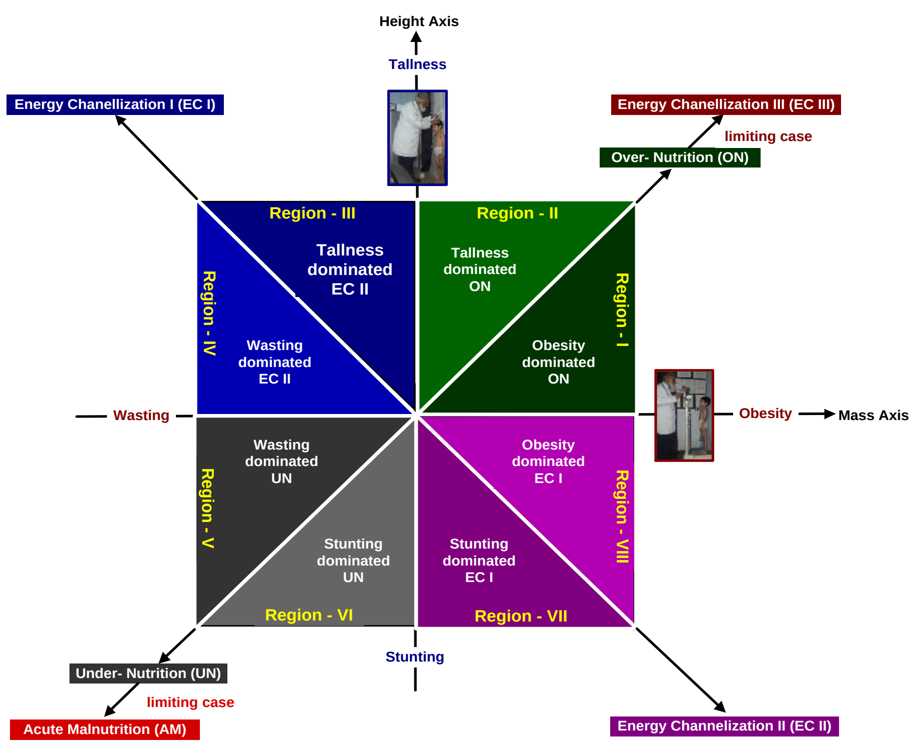



Fig. 10. Expanded classification of nutritional statuses based on polar-coördinate interpretation — limiting cases illustrated**:** color-coding of Growth-and-Obesity Vector-Roadmap 2.1, which includes color-coding of expanded classification of nutritional status is available in Additional File http://www.ngds-ku.org/Papers/J52/Additional_File.pdf

Table 3. Expanded classification of nutritional statuses based on polar-angle range

| *Region* | *Nutritional Status* | *Description* | *Polar-Angle Range (radian)* | *Polar-Angle Range (degree)* |
|---|---|---|---|---|
| I | Obesity dominated ON | Obesity dominating Tallness | $0 \le \theta < \frac{\pi}{4}$ | $[0, 45^0)$ |
| II | Tallness dominated ON | Tallness dominating Obesity | $\frac{\pi}{4} \le \theta < \frac{\pi}{2}$ | $[45^0, 90^0)$ |
| III | Tallness dominated EC I | Tallness dominating Wasting | $\frac{\pi}{2} \le \theta < \frac{3\pi}{4}$ | $[90^0, 135^0)$ |
| IV | Wasting dominated EC I | Wasting dominating Tallness | $\frac{3\pi}{4} \le \theta < \pi$ | $[135^0, 180^0)$ |
| V | Wasting dominated UN | Wasting dominating Stunting | $\pi \le \theta < \frac{5\pi}{4}$ | $[180^0, 225^0)$ |
| VI | Stunting dominated UN | Stunting dominating Wasting | $\frac{5\pi}{4} \le \theta < \frac{3\pi}{2}$ | $[225^0, 270^0)$ |
| VII | Stunting dominated EC II | Stunting dominating Obesity | $\frac{3\pi}{2} \le \theta < \frac{7\pi}{4}$ | $[270^0, 315^0)$ |
| VIII | Obesity dominated EC II | Obesity dominating Stunting | $\frac{7\pi}{4} \le \theta < 2\pi$ | $[315^0, 360^0)$ |

is given in Table 3. Build (Kamal and Khan, 2015) is assigned by taking sum of scaled percentiles and severity of acute malnutrition computed (Kamal *et al.*, 2017*b*).

*Growth-and-Obesity Scalar-Roadmaps* 2.1 (*for the periods of later childhood, transition and adolescence*)**:** Valid in the age ($A$) range, $9.5\, years \le A < 20\, years$, one requires two or more checkup profiles to construct these roadmaps. Reference-height percentile, $P_{\text{ref}}(A) = max\left(P_{\text{CDC}}(h, A), P_{\text{AC}}, P_{\text{MP}}\right)$, is computed. $\mu_{\text{opt}}$ is estimated based on reference height at $A_0$ (age at the most recent checkup) and $\mu_{\text{BMI}}$ from CDC percentile of *BMI*-based-optimal mass at $A_0$, both of them evaluated after a lapse of 6-*month* period. 6 monthly recommendations to pick up height and put on/shed off mass (range given instead of a single value) are generated from the most-recent profile.

*Growth-and-Obesity Vector-Roadmaps* 2.1 (*for the period of early childhood*)**:** Useful to study growth and obesity statuses of children till the age of 9.5 *years*, these roadmaps use the concepts of navigation, guidance and control. The navigational trajectories for height and mass percentiles are obtained by fitting freehand curves to the respective CDC height-and mass-percentile values, $P = P_{\text{CDC}}(h, A)$ and $P = P_{\text{CDC}}(\mu, A)$, the domain for navigational trajectory being $A_{\text{Enrolment}} \le A \le A_0$ ($A_{\text{Enrolment}}$ is age at enrolment/first checkup; control action needs to be initiated at $A_0$). The navigational trajectories are common for both Scalar- and Vector-Roadmaps 2.1. The domain for guidance trajectories (both height and mass management) is the closed interval $A_0 \le A \le 10\, years$ — control action ends at the age of 10 *years* in the context of Vector-Roadmap 2.1.

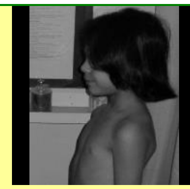
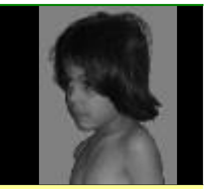
The guidance trajectory for height management takes the form, $P = P_{\text{ref}}(A)$, where $P_{\text{ref}}(A) = P_{\text{ref}}(A_0)$. A parabolic curve, $P = P_{\text{CDC}}(h, A)$, is fitted to generate trajectory of the desired course-of-action for height management, passing through $\left(A_0, P_{\text{CDC}}(h, A_0)\right)$, and touching, smoothly, the guidance trajectory, $P = P_{\text{ref}}(A)$, at the vertex $\left(10, P_{\text{ref}}(A_0)\right)$, in such a way that the guidance trajectory is tangent to parabola at this location. The guidance trajectories for mass management form the band, whose boundaries are given by $P = P_{\text{ref}}(A)$, where $P_{\text{ref}}(A) = P_{\text{ref}}(A_0)$, and $P = P_{\text{CDC}}(\mu_{\text{BMI}}, A)$, where $P_{\text{CDC}}(\mu_{\text{BMI}}, A) = P_{\text{CDC}}(\mu_{\text{BMI}}, A_0)$. 6 monthly targets for mass and height management are generated by erecting lines parallel to the vertical (percentile) axis.

Sample Vector-Roadmap 2.1 of M. E. is given in Tables 4*a*, *b*, which include modified statuses, descriptive statuses, away-from-normality index, $r$, polar angle, $\theta$, expanded nutritional status and 6 monthly recommendations for mass and height management. Time evolution of CDC percentiles of height and mass for M. E.'s 2 checkups is

Table 4*a*. Growth-and-Obesity Vector-Roadmap 2.1 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* | *1st* | *2nd* |
|---|---|---|
| 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*), *A* | 8.66 | 9.14 |
| Dress Code [ϕ] | 0/0.5[ϕ] | 0/0.5 [ϕ] |
| Behavior Code [ϕ] | 0[ϕ] | 0 [ϕ] |
| Height, *h* (*cm*) | 129.50[£] | 131.00[£] |
| Height (*ft-in*) | 4 *ft* 2.98 *in* | 4 *ft* 3.57 *in* |
| CDC Percentile-of-Height, $P_{CDC}(h, A)$ | 39.73[£] | 34.33[£] |
| Scaled Percentile-of-Height, $P_{Scaled}(h, A)$ | 49.70 | 43.72 |
| Estimated-Adult Height (*cm*) | 161.54 | 160.60 |
| **Estimated-Adult Height (*ft–in*)** | **5 *ft* 3.60 *in*** | **5 *ft* 3.23 *in*** |
| CA-MP (Current-Age-Mid-Parental) Height (*cm*) | 130.76 | 133.20 |
| Δ Height *w. r. t.* CA-MP Height (*cm*) | –1.26 | –2.20 |
| Modified Status (pertaining-to-height), $STATUS_{\pm}^{MOD}(h)$ | 0 | 0 |
| **Descriptive Status (pertaining-to-height)** | **Normal** | **Normal** |
| CA-AC (Current-Age-Army-Cutoff) Height (*cm*) | 125.78 | 128.06 |
| Δ Height *w. r. t.* CA-AC Height (*cm*) | +3.72 | +2.94 |
| Reference Height (*cm*) | 130.76 | 133.20 |
| Percentile-of-Reference-Height, $P_{ref}(A)$ | 47.49 | 47.49 |
| Net Mass, $\mu$ (*kg*) | 31.90 | 31.79 |
| Net Weight (*lb-oz*) | 70 *lb* 5.43 *oz* | 70 *lb* 1.55 *oz* |
| CDC Percentile-of-Net-Mass, $P_{CDC}(\mu, A)$ | 75.79 | 63.42 |
| Scaled Percentile-of-Net-Mass, $P_{Scaled}(\mu, A)$ | 83.43 | 73.09 |
| CDC Percentile-of-*BMI*-based-Optimal-Mass, $P_{CDC}(\mu_{BMI}, A)$ | 64.44 | 62.05 |
| *BMI*-based-Optimal-Mass, $\mu_{BMI}$ (*kg*) | 30.03 | 31.56 |
| Height-Percentile-based-Optimal Mass, $\mu_{opt}$ (*kg*) | 26.57 | 27.45 |
| Estimated-Adult Mass (*kg*) | 66.35 | 62.32 |
| Estimated-Adult Weight (*lb–oz*) | 146 *lb* 4.86 *oz* | 137 *lb* 6.54 *oz* |
| Modified Status (pertaining-to-mass), $STATUS_{\pm}^{MOD}(\mu)$ | +6.21% | +0.73% |
| **Descriptive Status (pertaining-to-mass)** | **1st-Deg Obese** | **1st-Deg Obese** |
| Away-from-Normality Index, *r* | 0.0621 | 0.0073 |
| Polar Angle, $\theta$ | 0 | 0 |
| **Expanded Nutritional Status** | **Obesity** | **Obesity** |
| Estimated-Adult *BMI* ($kg/m^2$) | 25.43 | 24.16 |
| $P_{Scaled}(h, A) + P_{Scaled}(\mu, A)$ | 133.14 | 116.81 |
| **Build** | **Medium** | **Medium** |

[§]The superscript P stands for percentile.

[ϕ]'Dress Code' 0/0.5 implied that the child was measured wearing panties only, barefoot, all clothing above the waist removed; 'Behavior Code' 0 means the child was relaxed and cooperative (Kamal, 2016*a*; Kamal *et al.*, 2002)

[£]'Pseudo-gain of height' (Kamal *et al.*, 2014*b*) exhibited between 1st and 2nd checkups — height pick-up from 129.50 *cm* to 131.00 *cm*, percentile dropping from 39.72 to 34.74

Table 4*b*. Month-wise targets of mass (weight) range and height, determined using Growth-and-Obesity Vector-Roadmap 2.1, for M. E. based on her last checkup

*Date of Last* (*Second*) *Checkup*: November 13, 2011 • *Decimal Age*, $A_0 = 9.139726027$ *years*

$P_{ref} = 47.49439769505168$ • $P_{CDC}(h, A_0) = 34.33112094538$ • $P_{CDC}(\mu, A_0) = 63.421313127254$

| *Target Date* | *Range of Mass (Weight) Targets* | | *Height Targets* | |
|---|---|---|---|---|
| | *kg* | *lb-oz* | *cm* | *ft-in* |
| December 13, 2011 | 31.64-32.04 | 69 *lb* 12.26 *oz* - 70 *lb* 10.48 *oz* | 131.80 | 4 *ft* 3.89 *in* |
| January 13, 2012 | 31.52-32.37 | 69 *lb* 8.03 *oz* - 71 *lb* 5.97 *oz* | 132.59 | 4 *ft* 4.32 *in* |
| February 13, 2012 | 31.44-32.70 | 69 *lb* 5.20 *oz* - 72 *lb* 1.52 *oz* | 133.33 | 4 *ft* 4.49 *in* |
| March 13, 2012 | 31.40-33.01 | 69 *lb* 3.79 *oz* - 72 *lb* 12.42 *oz* | 134.00 | 4 *ft* 4.76 *in* |
| April 13, 2012 | 31.42-33.35 | 69 *lb* 4.50 *oz* - 73 *lb* 8.69 *oz* | 134.66 | 4 *ft* 5.02 *in* |
| May 13, 2012 | 31.49-33.70 | 69 *lb* 6.97 *oz* - 74 *lb* 4.94 *oz* | 135.29 | 4 *ft* 5.26 *in* |

illustrated in Figure 11.

*Obesity Profiles* 2.1 (*for the period of adulthood*): CDC percentiles of heights and masses of parents/non-parents computed using linear interpolation from lesser and greater age-20 values read from extended-gender-specific tables. Modified and descriptive statuses (pertaining-to-mass) were evaluated on the basis of height-percentile-based as well as *BMI*-based optimal masses, scaled percentiles determined and build assigned.

*Obesity Roadmaps* 2.1 (*for the period of adulthood*): Instead of a single value of optimal mass, a range is available for the parents/non-parents to maintain their masses in such a way that after 6 *months* their masses should lie between $min\left(\mu_{opt}(A_0 + 6\,months), \mu_{BMI}(A_0 + 6\,months)\right)$ and $max\left(\mu_{opt}(A_0 + 6\,months), \mu_{BMI}(A_0 + 6\,months)\right)$. Individual was advised to maintain mass (weight) in the light of the above range, taking care of the principle that the incumbent should not be required to lose more than 10 *kg* within 6-*month* period, in order to avoid any adverse effects from a rapid loss of mass.

***Version* 2.1— *Software Development***

Software was developed to generate Growth-and-Obesity Vector-Roadmap 2.1. This software was named SOFTGROWTH 2.1. The software was developed in Microsoft Visual Studio (Visual Basic Dot Net 2008), which is an enhancement of SOFTGROWTH 2, whose features are reported earlier (Kamal *et al.*, 2017*a*). Version 2.1 is different from version 2 in the age ranges. Age-range interval, $A \geq 30$ *years*, $20\ years \leq A < 30\ years$, has been merged as $A \geq 20$ *years* (adulthood range). Both height-percentile-based and *BMI*-based optimal masses are now calculated and a range of mass values assigned for mass-management targets. For ages below 20 *years*, height management, also, plays a role and height-management targets are, also, given. Modified, descriptive as well as fractional statuses (pertaining-to-height) and (pertaining-to-mass) were computed and build assigned. Block diagram of SOFT-

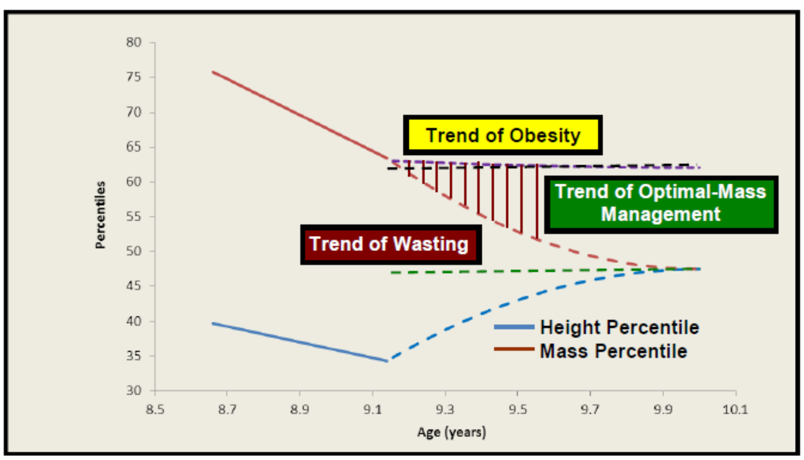



Fig. 11. Time evolution of CDC height and mass percentiles of M. E. for her two checkups in the age range 8.66-9.14 *years* (navigational trajectories: solid curves), including the desired course-of-action (guidance trajectories: green-dashed line for reference percentile; black-dashed line for *BMI*-based-optimal-mass percentile) and recommended intervention (control action: blue-dashed for height-percentile curve and maroon-shaded for mass-percentile curve) — The figure, also, illustrates trends of obesity, optimal-mass management and wasting

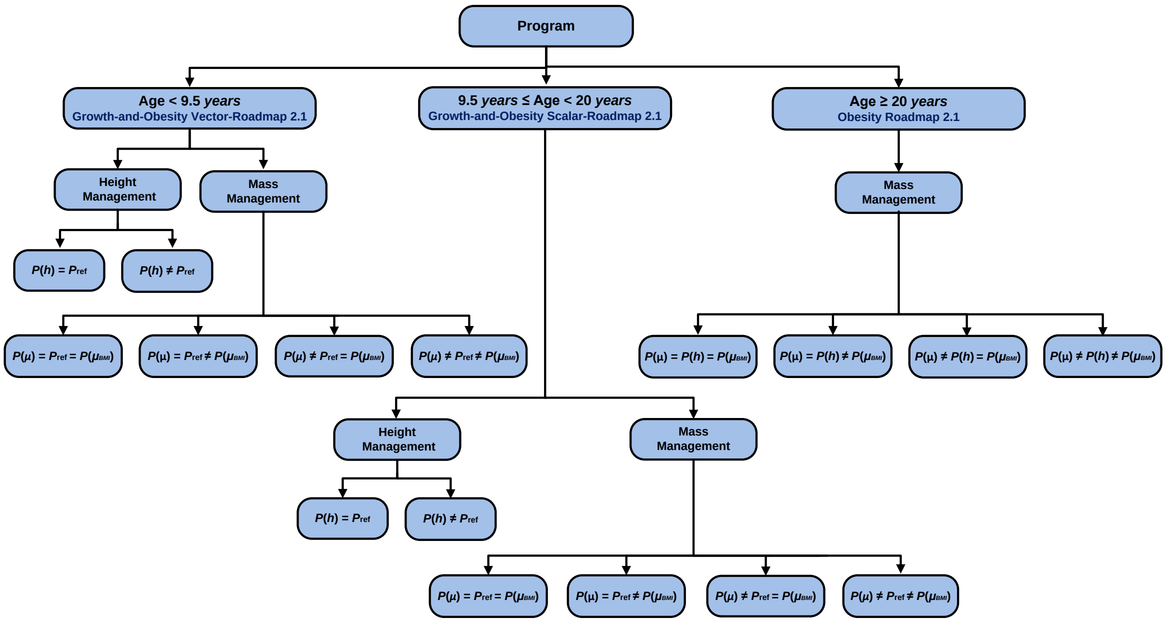



Fig. 12*a*. Block diagram of SOFTGROWTH 2.1

GROWTH 2.1 is given in Figure 12*a*. Screen shots of month-wise targets of parents of M. E. are displayed in Figures 12*b*, *c*.

## MATHEMATICS OF OBESITY AND WASTING BASED ON VERSION 2.1

The terms 'instantaneous obesity' and 'instantaneous wasting' were introduced (Kamal *et al.*, 2017*c*) and later defined mathematically (Kamal, 2017*c*) to differentiate them from 'true obesity' and 'true wasting' (Kamal *et al.*, 2017*a*).

### *Instantaneous Obesity*

Instantaneous obesity exists, when modified status (pertaining-to-mass) is greater than zero. Definition of instan-


Fig. 12*b*. SOFTGROWTH 2.1 screen shot of month-wise targets of mass (weight) range for father of M. E.

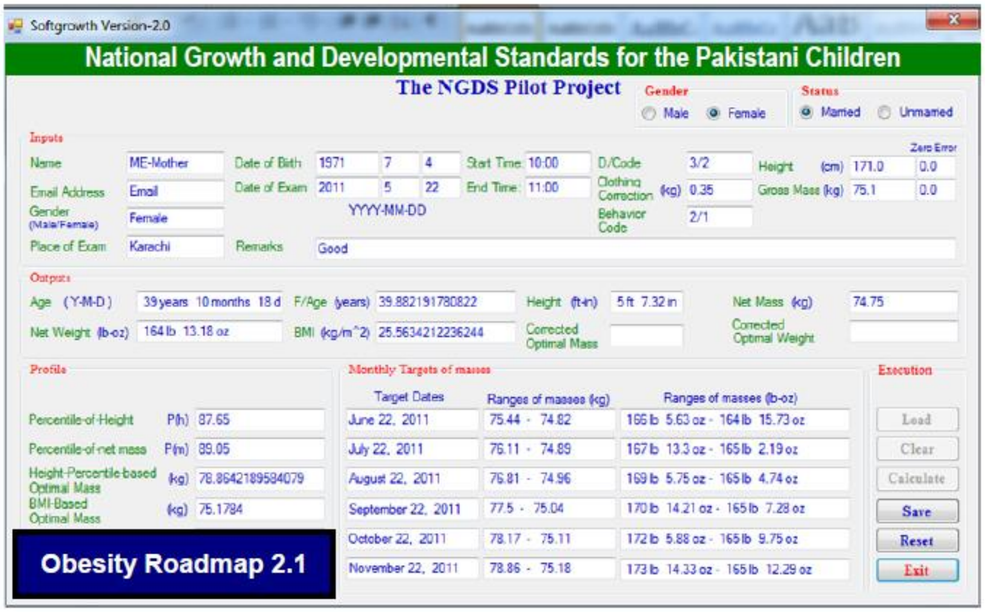



Fig. 12*c*. SOFTGROWTH 2.1 screen shot of month-wise targets of mass (weight) range for mother of M. E.

taneous obesity is given in Table 5 and clinical example available in Table 6, demonstrated during all of the check-ups of Z. J. (SGPP-KHI-20060412-01/01), the case documented in Kamal (2017*a*).

Table 5. Logical and mathematical definitions of instantaneous obesity and true obesity.

| | *Instantaneous Obesity* | *True Obesity* |
|---|---|---|
| *Logical Definition* | $\mu - \mu_{\max} > 0,\ \mu_{\max} = max(\mu_{\text{opt}}, \mu_{\text{BMI}})$ | $\mu_{\max}^{\text{REC}}(A_0 + 6\ months) - \mu(A_0) < 0$ |
| *Mathematical Definition* | $STATUS_{\pm}^{\text{MOD}}(\mu) > 0$ | $P_{\text{CDC}}(\mu, A_0) - max\left(P_{\text{ref}}(A_0), P_{\text{BMI}}(\mu, A_0)\right) > +15$ |

***True Obesity***

True obesity exists, when the youngster's recommended upper value of mass (weight) range at the end of 6-*month*

Table 6. Z. J. demonstrates instantaneous obesity and true obesity during all of her checkups.

| | *Existence of Instantaneous Obesity* $STATUS_{\pm}^{\text{MOD}}(\mu)^{\beta}$ | *Existence of Tue Obesity* $\Delta\mu^{\kappa}; P_{\text{CDC}}(\mu, A_0) - max\left(P_{\text{ref}}(A_0), P_{\text{BMI}}(\mu, A_0)\right)^{\tau}$ |
|---|---|---|
| *1st Checkup* | $+14.61\,\% > 0^{\lambda}$ | $-3.48\ kg < 0; +21.60 > +15$ |
| *2nd Checkup* | $+18.04\,\% > 0^{\mu}$ | $-5.10\ kg < 0; +23.69 > +15$ |
| *3rd Checkup* | $+13.56\,\% > 0^{\nu}$ | $-3.58\ kg < 0; +17.97 > +15$ |

$^{\beta}$Instantaneous obesity exists when $STATUS_{\pm}^{\text{MOD}}(\mu) > 0$

$^{\kappa}$Logical definition**:** $\Delta\mu = \mu_{\max}^{\text{REC}}(A_0 + 6\ months\ ) - \mu(A_0) < 0$

$^{\tau}$Mathematical definition**:** $P_{\text{CDC}}(\mu, A_0) - max\left(P_{\text{ref}}(A_0), P_{\text{BMI}}(\mu, A_0)\right) > +15$

$^{\lambda}$Obtained from rounding off the number $100\ \dfrac{42.50 - 37.0820027676\ \ 6469}{37.0820027676\ \ 6469} = +\mathbf{14.6108}5385889614$

$^{\mu}$Obtained from rounding off the number $100\ \dfrac{46.50 - 39.3943550368\ \ \ 1415}{39.3943550368\ \ \ 1415} = +\mathbf{18.0372}1613552399$

$^{\nu}$Obtained from rounding off the number $100\ \dfrac{49.60 - 43.6788504324\ \ \ 5406}{43.6788504324\ \ \ 5406} +\mathbf{13.5561}021156021$

Table 7. Logical and mathematical definitions of instantaneous wasting and true wasting

| | *Instantaneous Wasting* | *True Wasting* |
|---|---|---|
| *Logical Definition* | $\mu - \mu_{\min} < 0, \mu_{\min} = min\ (\mu_{opt}, \mu_{BMI})$ | $P_{CDC}(\mu, A_0) - P_{\min}^{REC}(\mu, A_0 + 6\ months) < 0$ |
| *Mathematical Definition* | $STATUS_{\pm}^{MOD}(\mu) < 0$ | $P_{CDC}(\mu, A_0) - min\ (P_{ref}(A_0), P_{BMI}(\mu, A_0)) < 0$ |

period is lesser than net mass at the most-recent checkup — logical definition. A mathematical definition has, also, been proposed, which classifies the child as truly obese, when the difference of the incumbent's CDC mass percentile and maximum of the reference percentile at the most-recent checkup and *BMI*-based-optimal mass, both of them computed at the most recent checkup exceeds 15 (Table 5). Presented in Table 6 are examples of true obesity, demonstrated during all of the checkups of Z. J. Proof of true obesity implying instantaneous obesity based on modified status (pertaining-to-mass) is given in Appendix A.

***Instantaneous Wasting***

Instantaneous wasting exists, when modified status (pertaining-to-mass) is less than zero. Definition of instantaneous  is given in Table 7 and clinical example available in Table 8, demonstrated during all of the checkups of L. G. (SGPP-KHI-20131021-02/01), the case documented in Kamal *et al.* (2017*b*).

***True Wasting***

A child is termed as truly wasted if the incumbent is recommended to climb on the trajectory of CDC percentile-of-mass within the next 6 *months* to the minimum of the reference percentile at the most-recent checkup and *BMI*-based-optimal mass, also, at the most recent checkup. A mathematical definition has, also, been proposed, which classifies the child as truly wasted, when the difference of the youngster's CDC mass percentile at the most recent checkup and the minimum of the reference percentile at the most-recent checkup and *BMI*-based-optimal mass, also, at the most recent checkup is negative (Table 7). Equivalence of logical and mathematical definitions of true wasting is proved in Appendix B. Further, it is shown that instantaneous wasting implies true wasting. However, the converse is not true. Presented in Table 8 are examples of true wasting, demonstrated during all of the checkups of L. G. Proof of instantaneous wasting implying true wasting based on modified status (pertaining-to-mass) is given in Appendix B.

It must be emphasized that not all the scenarios, which involve recommendation of mass gain by a child, corresponding to true wasting. All such possibilities are listed in Appendix C.

## LIFESTYLE ADJUSTMENT, DIET AND EXERCISE PLANS

In order to achieve height- and mass-management targets proposed by Growth-and-Obesity Vector-Roadmap 2.1, lifestyle, diet and exercise plans have been prepared (Table 9), which are extended and refined from previous

Table 8. L. G. demonstrates instantaneous wasting and true wasting during all of her checkups.

| | *Existence of Instantaneous Wasting* $STATUS_{\pm}^{MOD}(\mu)^{\alpha}$ | *Existence of Tue Wasting* $\Delta P^{\delta}; P_{CDC}(\mu, A_0) - min\ (P_{ref}(A_0), P_{BMI}(\mu, A_0))^{\theta}$ |
|---|---|---|
| *1st Checkup* | $-10.28\% < 0$ | $-7.62 < 0; -23.07 < 0^{\#}$ |
| *2nd Checkup* | $-19.42\% < 0$ | $-10.88 < 0; -30.03 < 0$ |
| *3rd Checkup* | $-17.53\% < 0$ | $-10.39 < 0; -23.30 < 0$ |
| *4th Checkup* | $-19.44\% < 0$ | $-15.75 < 0; -26.54 < 0*$ |

$^{\alpha}$Instantaneous wasting exists when $STATUS_{\pm}^{MOD}(\mu) < 0$

$^{\delta}$Logical definition**:** $\Delta P = P_{CDC}(\mu, A_0) - P_{\min}^{REC}(\mu, A_0 + 6\ months) < 0$

$^{\theta}$Mathematical definition**:** $P_{CDC}(\mu, A_0) - min\ (P_{ref}(A_0), P_{BMI}(\mu, A_0)) < 0$

$^{\#}$Obtained from rounding off the number **51.30697**04525242 – **74.3758**4574646 = –**23.0663**880049404

*Obtained from rounding off the number 6**5.2854**556480498 – **91.8244**8368775 = –**26.5390**2803970095

Table 9. Lifestyle adjustment, diet and exercise plans[¶] for children to achieve month-wise targets.

<table>
<tr><th></th><th>Height Management</th><th>Mass (Weight) Management</th></tr>
<tr><td>Lifestyle Adjustment</td><td colspan="2">2-3-hour family time on a daily basis, with cell phones and tablets kept away (conversation — parents should educate children about environmental-resource preservation: trees and forests, water reservoirs, clean-fresh air, plastic pollution; religious tolerance; ethnic diversity; empathy to feeling of others; joy of sharing); parents may stroll in the park/relax on benches, while children engage in free play; 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 (head, arms, legs and spinal column exposed, last one from external auditory meatus to hip joint; facing away from sun and eyes protected through UV (ultraviolet)-cutoff glasses or indigenously-made spectacles[ρ]; hair spread out and opened up and bare (dried) feet (to prevent fungus infection); 2-3-hour play in fresh air to spread-out hair, stripped-to-waist, wearing pure cotton socks and sneakers; hair and body massage with olive oil before bathing; 8-hour, night-time, sound sleep dressed in fire-resistant pajama-shorts only, stripped-to-waist[@]; 3-minute, slow-stoke back massage to improve quality and quantity of sleep — before retiring to bed (girls') hair unbraided and opened up[χ], all hair accessories, jewelry, watch, belt removed; glass of milk consumed before bedtime; teeth brushed 5 times — upon rising, after breakfast, lunch and dinner each as well as before going to bed; additional brushing after consuming candies/chocolates/cookies/ juices/milk; maximum 2-hour screen time (computer/video games/TV/DVD — computer monitor at eye level, neck and back straight as well as normal to thighs); 2-strap school bags worn on back with each strap on a shoulder (unnecessary books/copies/journals taken out); pure cotton under-garments and socks (disinfectant powder to be applied to dry body parts and wiped feet before putting on underwear/socks), pure leather mocation shoes with foot support — tight undergarments, clothes, shoes and slippers (flip-flops) should not be worn, slippers got wet during ablution should be replaced immediately with dry ones to be put on carefully dried and feet wiped between toes (same goes on with clothes drenched in rain, etc.); absolutely NO high heels for girls — cause toes to bend inward</td></tr>
<tr><td rowspan="2">Diet Plans</td><td colspan="2">3 relaxed (wait for food, not let the food wait for you; no eating/drinking while walking or standing; eat when very hungry, abstain when some appetite remains) and balanced meals, should include fresh fruits and green vegetables; 10-12 glasses of water daily; only one 250-ml bottle of carbonated drink in a month[&]</td></tr>
<tr><td>To gain height, diet plan should include calcium-, protein- and fiber-rich diet (chicken, fish, fresh fruit and milk)</td><td>To put on mass (weight), diet plan should include milk, potato items (baked/boiled, not fried) and protein-rich diet; to shed off mass, 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 writing, stretching, touching toes without flexing knees, exercising neck muscles (left, right, up, down), light exercises during TV/DVD watching; guarded-graduated[©] structured exercises, preceded by warm-up and followed by cool-down routines, preferably outdoors (weather permitting) in exercise-friendly clothing[∍] — form-fitting, made of absorbent material; table tennis; jogging; cycling</td></tr>
<tr><td>To pick up height, child should perform light-stretching exercises (bar hanging, mild-stretching, summersault, cartwheel)</td><td>To increase mass (weight), heavy exercises performed for shorter duration, consistently; to lose mass (weight), child should perform light exercises for longer duration, consistently</td></tr>
</table>

[¶] Diet and exercise plans compiled from Kamal *et al.* (2013*b*, *c*)

[¥] According to the Consensus Report of the Institute of Medicine (November 30, 2010) — 1 IU (International Unit, established by WHO in 1931) of vitamin D equivalent to 0.025 $\mu g$ of cholecalciferol or ergocalciferol; remedial measures to overcome vitamin-D deficiency are given in Kamal *et al.* (2013*a*) as well as Kamal and Khan (2018)

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

[ρ] made from one layer of completely-exposed photographic film, ASA 100, having high sliver content, 2 layers needed to observe partial-solar eclipse (Kamal, 2018)

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

[χ] Allowing hair to breathe during night

[&] 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

[©] Guarded-graduated exercises should contribute towards health- as well as skill-related fitness (performance considera-tions). Such practices, also, avoid exercise-related injuries (safety considerations); 'guarded' 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)

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

## CONCLUSION AND FUTURE DIRECTIONS

Childhood obesity is a major issue globally, obesity being a complicated condition influenced by interactions between genetic and environmental factors. The true prevalence of childhood obesity becomes difficult to quantify in the absence of a universally accepted definition. Our research group has proposed mathematical and logical definitions of instantaneous obesity and true obesity. In this paper, mathematical-statistical solutions of childhood obesity, presented during 2013-2017, have been enhanced. Growth-and-Obesity Scalar- and Vector-Roadmaps have been simplified by modifying definitions of statuses (pertaining-to-height) and (pertaining-to-mass). Both of these statuses, expressed as fractional statuses, have been combined to write fractional status (pertaining-to-height-and-mass), which is a complex number. Magnitude of this complex number represents away-from-normality index.

Future work should focus on extending Growth-and-Obesity Vector-Roadmaps to include still-growing parents. Further, scaled percentile transformation equations should be formulated based on analysis of data of the Pakistani children. The long-term term goals should include enhancement of anthropometric instruments to measure heights and masses to least counts of 0.001 *cm* and 0.005 *kg*, respectively. In addition, Growth Charts and Tables for the Pakistani children should be constructed.

It is through improving health and emotional status of the Pakistani children that the dream of making this nation a regional power could be realized.

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## APPENDIX A: PROOF OF TRUE OBESITY

### Already known on this topic

Childhood obesity a prime concern for global health, obesity is a complicated condition, which is influenced by interactions between environmental and genetic factors

The true prevalence of childhood obesity difficult to quantify as there is no universally accepted definition available at present

*BMI* still the most popular index for classifying fatness and thinness

Various definitions of obesity proposed include relative *BMI*, cutoff point as 30 $kg/m^2$ (adult *BMI*), *BMI* ranges (below $85^P \rightarrow$ normal, $85^P$ to $95^P \rightarrow$ intermediate, equal to or above $95^P \rightarrow$ high)

### The NGDS Team (our group) contributions

**2004** Height-percentile-based-optimal mass (name mention as 'optimal mass'; formal definition in 2011)

**2011** Statuses (pertaining-to-height) and (pertaining-to-mass); only 'obese' and 'wasted' used with percentage indicating severity instead of overweight, fat, underweight, lean

**2012** Estimated-adult *BMI*; model extended to still-growing parents

**2013-2017** $1^{st}$- to $6^{th}$-generation solutions of childhood obesity

**2014** Energy-channelization I-III; pseudo-gain of mass/height; use of percentile trajectories of height/mass instead of growth (height) velocity/ rate of mass gain/loss; CDC Growth Tables extended to include percentiles in the range $0.01^{th}$ to $99.99^{th}$ (to handle extreme cases)

**2015** Month-wise targets (next 6 *months*) to shed-off mass; mathematical definition of build; formula to compute severity of acute malnutrition

**2016** Mass and height measurements to least counts of 0.005 *kg* and 0.005 *cm*, respectively, accompanied by manual, version 9.11

**2017** *BMI*-based-optimal mass; mathematical definition of childhood obesity (instantaneous obesity vs. true obesity); mathematical definition of childhood wasting (instantaneous wasting vs. true wasting); validation of mathematical definition of childhood obesity based on anthropometric data collected during 1998-2013

**2017** Mathematical criteria to classify normal, early, delayed and precarious puberty through scaled percentiles; assignment of Tanner scores to prepubertal, peripubertal, pubertal, adolescent and adult stages

### This work adds

Integration of height-percentile-based-optimal mass with *BMI*-based-optimal mass to modify definitions of statuses (pertaining-to-height) and (pertaining-to-mass) — $7^{th}$-generation solution of childhood obesity (Growth-and-Obesity Vector-Roadmaps 2.1)

Polar-coördinate representation of nutritional-status classification

Extension of nutritional-status classification from 6 to 10 categories

### The next step

Four mathematical equations to convert CDC percentiles to scaled percentiles generated from indigenously-collected anthropometric data

Growth-and-Obesity Vector-Roadmaps 3.0 for children of still-growing parents

## IMPLYING INSTANTANEOUS OBESITY BASED ON MODIFIED STATUS (PERTAINING-TO-MASS)

One needs to prove $\mu_{\max}^{\text{REC}}(A_0 + 6\ months) - \mu(A_0) < 0 \Rightarrow STATUS_{\pm}^{\text{MOD}}(\mu) > 0.$ In other words, if a child is recommended to lose mass within a time span of 6 *months* (condition of true obesity), such a child must exhibit instantaneous obesity (Table 4).

(A1) $$\mu_{\max}^{\text{REC}}(A_0 + 6\ months) - \mu(A_0) < 0 \Rightarrow \mu(A_0) > \mu_{\max}^{\text{REC}}(A_0 + 6\ months)$$

The function, $P = P_{\text{CDC}}(\mu, A_0)$, generating CDC percentiles-of-masses, $P_{\text{CDC}}(\mu, A_0)$, from values of masses, $\mu(A_0)$, is a monotonically increasing function of masses, provided the age, $A_0$, is kept constant, as noted by inspecting Additional File 3 of Kamal and Jamil (2014). The same holds for inverse function, $\mu = P_{\text{CDC}}{}^{-1}(\mu, A_0)$, generating masses, $\mu(A_0)$, from values of CDC percentiles-of-masses, $P_{\text{CDC}}(\mu, A_0)$. In layman's language, mass increases with the advancing percentile, for a given age, and vice versa.

However, with the advancing age, this might not hold true as a slight gain in mass could be accompanied by a drop in percentile — phenomenon of pseudo-gain of mass, as mentioned in Table 6 (Kamal *et al.*, 2014*b*). On the other hand, when there is a loss of mass as a child gets older, this loss may be true (Kamal, 2014 — Additional File) or recommended (Table 4) — phenomenon of true obesity (Kamal, 2017*a*), it is, always, associated with a drop in percentile. This could, also, be observed by looking at Additional File 3 of Kamal and Jamil (2014). Hence

(A2) $$P_{\text{CDC}}(\mu, A_0) > P_{\max}^{\text{REC}}(\mu, A_0 + 6\ months)$$

Now

(A3) $$P_{\max}^{\text{REC}}(\mu, A_0 + 6\ months) > max\left(P_{\text{ref}}(A_0), P_{\text{BMI}}(\mu, A_0)\right)$$

as the percentile must decrease to this value at the age of 10 *years*, in case of true obesity. By applying transitive property of inequalities to (A2) and (A3), one concludes

(A4) $$P_{\text{CDC}}(\mu, A_0) > max\left(P_{\text{ref}}(A_0), P_{\text{BMI}}(\mu, A_0)\right)$$

Again invoking the functional property of percentile of mass, mentioned below (A1), one infers

(A5) $$\mu(A_0) > max(\mu_{\text{opt}}, \mu_{\text{BMI}})$$

Recognizing $\mu_{\max} = max(\mu_{\text{opt}}, \mu_{\text{BMI}})$

(A6) $$\mu > \mu_{\max} \Rightarrow 100\ \frac{\mu - \mu_{\max}}{\mu_{\max}} > 0 \Rightarrow STATUS_{\pm}^{\text{MOD}}(\mu) > 0.$$

This completes the proof.

The converse is not true, *i. e.*, $STATUS_{\pm}^{\text{MOD}}(\mu) > 0 \not\Rightarrow \mu_{\max}^{\text{REC}}(A_0 + 6\ months) - \mu(A_0) < 0$, which is illustrated by the following counter example**:**

Consider the case of M. E., presented in Tables 8*a*, *b*. At the time of her 2nd checkup, conducted on November 13, 2011, she was 9 *year*s 1 *month* 20 *days* old (decimal age, $A_0 = 9.139726027$ *years*). Her mass was recorded as 31.70 *kg*. She was advised to maintain a mass between 31.49 *kg* and 33.70 *kg*, at the end of 6-*month* period. She was 1st-degree obese, since $STATUS_{\pm}^{\text{MOD}}(\mu) = +0.73\%.$ However, $\mu_{\max}^{\text{REC}}(A_0 + 6\ months) = 33.70\ kg, \mu(A_0) = 31.70\ kg,$ Therefore

$$\mu_{\max}^{\text{REC}}(A_0 + 6\ months) - \mu(A_0) = +2.00\ kg \Rightarrow \mu_{\max}^{\text{REC}}(A_0 + 6\ months) - \mu(A_0) \not< 0$$

This is a demonstration that M. E. is not demonstrating true obesity.

## APPENDIX B: PROOF OF INSTANTANEOUS WASTING IMPLYING TRUE WASTING BASED ON MODIFIED STATUS (PERTAINING-TO-MASS)

The lengthy proof given in Appendix B of Kamal (2017*b*) takes a very simple form, when modified status (pertaining-to-mass) is used, *i. e.*, instantaneous wasting implies true wasting.

First of all, one proves that the logical and the mathematical definitions of true wasting are equivalent, *i.e.*,

$$P_{\text{CDC}}(\mu, A_0) - P_{\text{CDC}}^{\text{REC}}(\mu, A_0 + 6\ months) < 0 \Leftrightarrow P_{\text{CDC}}(\mu, A_0) - min\left(P_{\text{ref}}(A_0), P_{\text{BMI}}(\mu, A_0)\right) < 0$$

The above statement is equivalent to

(B1*a*) $$P_{CDC}(\mu, A_0) - P_{CDC}^{REC}(\mu, A_0 + 6\ months) < 0 \Rightarrow P_{CDC}(\mu, A_0) - min\left(P_{ref}(A_0), P_{BMI}(\mu, A_0)\right) < 0$$

and

(B1*b*) $$P_{CDC}(\mu, A_0) - P_{CDC}^{REC}(\mu, A_0 + 6\ months) < 0 \Leftarrow P_{CDC}(\mu, A_0) - min\left(P_{ref}(A_0), P_{BMI}(\mu, A_0)\right) < 0$$

To prove (B1*a*), one notes that for true wasting the child is recommended to climb on the curve, representing CDC percentile-of-mass, to tangentially approach at the end of intervention period (the reference age, taken as 10 *years*), the line segment representing minimum of reference percentile, $P_{ref}(A_0)$, and *BMI*-based-optimal-mass percentile, $P_{BMI}(A_0)$, starting at age of the most-recent checkup, $A_0$, and terminating at the reference age, in the process gaining mass. Since the percentile curve, $P = P_{CDC}(\mu, A)$, is a monotonically increasing function of age, $A$, this is only possible, when the value of this minimum is greater than the value of mass percentile at age of the most-recent checkup, $P_{CDC}(\mu, A_0)$. The converse, (B1*b*), can be easily proved by the same line of argument.

The proof of instantaneous wasting implying true wasting, using modified status (pertaining-to-mass), is now given using the mathematical definition of true wasting. Noting that instantaneous wasting is defined as**:**

(B2) $$STATUS_{\pm}^{MOD}(\mu) < 0 \Rightarrow 100\,\frac{\mu - \mu_{min}}{\mu_{min}} < 0 \Rightarrow \mu < \mu_{min},\ \mu_{min} = min(\mu_{opt}, \mu_{BMI})$$

*Case* 1**:** $\mu_{opt} < \mu_{BMI} \Rightarrow \mu_{min} = \mu_{opt} \Rightarrow \mu < \mu_{opt}$, from (B2). Since the CDC percentile-of-mass, $P_{CDC}(\mu, A_0)$, is a monotonically increasing function of mass, $\mu(A_0)$, provided age, $A_0$, is kept constant — observation below (A1), one writes

(B3) $$P_{CDC}(\mu, A_0) < P_{CDC}(h, A_0);\ \text{noting that}\ P_{CDC}(\mu_{opt}, A_0) = P_{CDC}(h, A_0)$$

By definition,

(B4) $$P_{CDC}(h, A_0) \le P_{ref}(A_0)$$

Applying transitive property of equations cum inequalities

(B5) $$a < b, b < c \Rightarrow a < c; a < b, b \le c \Rightarrow a < c; a \le b, b < c \Rightarrow a < c; a \le b, b \le c \Rightarrow a \le c$$

to (B3) and (B4), one concludes $\boxed{P_{CDC}(\mu, A_0) < P_{ref}(A_0)}$

Also, $\mu_{opt} < \mu_{BMI} \Rightarrow P_{CDC}(h, A_0) < P_{BMI}(\mu, A_0)$, based on comment below (A1) and explanation given in (B3). Again applying (B5) to $P_{CDC}(\mu, A_0) < P_{CDC}(h, A_0)$, as given in (B3), and $P_{CDC}(h, A_0) < P_{BMI}(\mu, A_0)$, one concludes

(B6) $$\boxed{P_{CDC}(\mu, A_0) < P_{BMI}(\mu, A_0)} \Rightarrow \boxed{P_{CDC}(\mu, A_0) < min\left(P_{ref}(A_0), P_{BMI}(\mu, A_0)\right)}$$

which is the mathematical definition of true wasting (Table 5). Hence, it is proved that in case 1, instantaneous wasting implies true wasting. The comment given below (B1*b*) is, also, applicable here.

*Case* 2**:** $\mu_{BMI} < \mu_{opt} \Rightarrow \mu_{min} = \mu_{BMI} \Rightarrow \mu < \mu_{BMI}$, as concluded from (B2). Again employing observation below (A1) regarding functional dependence of CDC percentile-of-mass on child's net mass, one writes

(B7) $$\boxed{P_{CDC}(\mu, A_0) < P_{BMI}(\mu, A_0)}$$

Further by the supposition in this case, $\mu_{BMI} < \mu_{opt} \Rightarrow P_{BMI}(\mu, A_0) < P_{CDC}(h, A_0)$, based on observation below (A1) and comment appearing in (B3). From the definition of reference percentile one concludes that, $P_{CDC}(h, A_0) \le P_{ref}(A_0)$. Applying transitive property of equations cum inequalities to $P_{CDC}(\mu, A_0) < P_{BMI}(\mu, A_0)$, $P_{BMI}(\mu, A_0) < P_{CDC}(h, A_0)$ and $P_{CDC}(h, A_0) \le P_{ref}(A_0)$, one obtains

$$\boxed{P_{CDC}(\mu, A_0) < P_{ref}(A_0)} \Rightarrow \boxed{P_{CDC}(\mu, A_0) < min\left(P_{ref}(A_0), P_{BMI}(\mu, A_0)\right)}$$

*Case* 3**:** $\mu_{BMI} = \mu_{opt} \Rightarrow \mu_{min} = \mu_{max} = \mu_{\Updownarrow}$. Now, $\mu_{\Updownarrow} = \mu_{BMI} = \mu_{opt} \Rightarrow P_{BMI}(\mu, A_0) = P_{CDC}(h, A_0)$, based on note in (B3) and comments after (A1). Since the child exhibits instantaneous wasting,

$$STATUS_{\pm}^{MOD}(\mu) < 0 \Rightarrow 100\,\frac{\mu - \mu_{\Updownarrow}}{\mu_{\Updownarrow}} < 0 \Rightarrow \mu < \mu_{\Updownarrow}$$

which translates to

(B8*a*, *b*) $\mu < \mu_{\text{BMI}}, \mu < \mu_{\text{opt}}$

Based on comments written after (A1), the above conditions become conditions on respective percentiles. (B8*a*) may, then, be expressed as (B7), *i. e.*,

$$\boxed{P_{\text{CDC}}(\mu, A_0) < P_{\text{BMI}}(\mu, A_0)}$$

and (B8*b*) as (B3). Further, by definition CDC percentile-of-height, $P_{\text{CDC}}(h, A_0)$, is lesser than or equal to reference percentile, $P_{\text{ref}}(A_0)$, as spelled out in (B4). Applying transitive property of equations cum inequalities (B5) to (B3) and (B4), one concludes

$$\boxed{P_{\text{CDC}}(\mu, A_0) < P_{\text{ref}}(A_0)}$$

which may be written as

$$\boxed{P_{\text{CDC}}(\mu, A_0) < min\left(P_{\text{ref}}(A_0), P_{\text{BMI}}(\mu, A_0)\right)}$$

This completes the proof.

The converse is not true, *i. e.*, $P_{\text{CDC}}(\mu, A_0) < min\left(P_{\text{ref}}(A_0), P_{\text{BMI}}(\mu, A_0)\right) \not\Rightarrow STATUS_{\pm}^{\text{MOD}}(\mu) < 0$, which is illustrated by the following counter example**:**

Consider the case of Z. H. Z. (SGPP-KHI-20110412-01/01; NGDS-BLA-2010-5484/Z), presented in Kamal (2017*a*). At the time of her 5th checkup, conducted on November 23, 2014, she was 9 *years* 5 *months* 7 *days* old (decimal age, $A_0 = 9.438356165$ *years*).

$$P_{\text{CDC}}(\mu, A_0) = 63.50,\ min\left(P_{\text{ref}}(A_0), P_{\text{BMI}}(\mu, A_0)\right) = min(76.12, 72.73) = 72.73$$

$$\Rightarrow P_{\text{CDC}}(\mu, A_0) < min\left(P_{\text{ref}}(A_0), P_{\text{BMI}}(\mu, A_0)\right)$$

Therefore, one notes that true wasting is *present*.

$$\mu = 33.06\ kg, \mu_{\text{min}} = min(\mu_{\text{opt}}, \mu_{\text{BMI}}) = min(32.12\ kg, 34.71\ kg) = 32.12\ kg \Rightarrow \mu > \mu_{\text{min}}$$

Hence, one concludes that instantaneous wasting is *not present*. Noting that

$$\mu_{\text{max}} = max(\mu_{\text{opt}}\ \mu_{\text{BMI}}) = max(32.12\ kg, 34.71\ kg) = 34.71\ kg \Rightarrow \mu < \mu_{\text{max}}$$

Therefore, $STATUS_{\pm}^{\text{MOD}}(\mu) \not< 0$, the modified status (pertaining-to-mass) being normal, instead of 1st-degree obese, which was previously determined by Growth-and-Obesity Vector-Roadmap 2.0 (Kamal, 2017*b*).

## APPENDIX C: THREE SCENARIOS, IN WHICH A CHILD IS RECOMMENDED TO GAIN MASS

Table 10 lists 3 scenarios and the associated mathematical conditions, in which a child is recommended to gain mass. These are true wasting, optimal-mass management and pseudo-gain of mass — the first one applicable, when CDC percentile of mass at the most-recent checkup is less than the minimum of CDC percentile of recommended mass at the end of 6-*month* period, the second one applicable, when CDC percentile of mass lies between minimum and maximum and the third one applicable, when CDC percentile of mass exceeds the minimum of CDC percentile of recommended mass at the end of 6-*month* period.

Table 10. Three scenarios, in which a child is recommended to gain mass[ϒ] within 6 *months*[⊕]

| *Difference of CDC Percentiles-of-Mass* | *Mass Management* |
|---|---|
| $P_{\text{CDC}}(\mu, A_0) < P_{\text{min}}^{\text{REC}}(\mu, A_0 + 6\ months)$ | True Wasting (Kamal, 2017*b*) |
| $P_{\text{min}}^{\text{REC}}(\mu, A_0 + 6\ months) \le P_{\text{CDC}}(\mu, A_0) \le P_{\text{max}}^{\text{REC}}(\mu, A_0 + 6\ months)$ | Optimal-mass management (Kamal, 2015*b*) |
| $P_{\text{max}}^{\text{REC}}(\mu, A_0 + 6\ months) < P_{\text{CDC}}(\mu, A_0)$[∀] | Pseudo-gain of mass (Kamal *et al.*, 2014*b*) |

ϒ $\mu_{\text{max}}^{\text{REC}}(A_0 + 6 months) - \mu(A_0) > 0$

⊕Modified version of Table 4 of Kamal (2017*b*)

∀Noting that $\mu_{\text{max}}^{\text{REC}}(A_0 + 6 months) - \mu(A_0) > \mu_{\text{min}}^{\text{REC}}(A_0 + 6 months) - \mu(A_0)$ and

$$\mu_{\text{min}}^{\text{REC}}(A_0 + 6 months) - \mu(A_0) > 0 \Rightarrow \mu_{\text{max}}^{\text{REC}}(A_0 + 6 months) - \mu(A_0) > 0$$

applying transitive property for inequalities. Combining this with $P_{\text{max}}^{\text{REC}}(\mu, A_0 + 6\ months) < P_{\text{CDC}}(\mu, A_0)$, this becomes definition of 'pseudo-gain of mass'

**REFERENCES**

Ansari, S. A. (2015). Generating and validating Growth-and-Obesity Roadmaps for the Pakistani children. *PhD Dissertation*, University of Karachi, Karachi, Pakistan (unpublished)

Berggren, S., J. Roswall, B. Alm, S. Bergman, J. Dahlgren and G. Almquist-Tangen (2018). Parents with overweight children two and five years of age did not perceive them as weighing too much. British Journal of Nutrition, 107 (6): 1060-1064.

Cole, T. J., M. C. Bellizzi, K. M. Flegal and W. H. Dietz (2000). Establishing a standard definition of child overweight and obesity worldwide**:** International survey. *British Medical Journal*, 320 (7244)**:** 1240-1243.

Covic, T., L. Roufiel and S. Dziurawiec (2007). Community beliefs about childhood obesity**:** Its causes, consequences and potential solutions. *Journal of Public Health*, 29 (2)**:** 123-131.

Fagg, J., P. Chadwick, T. J. Cole, *et al.* (2014). From trial to population**:** A study of family-based community intervention for childhood overweight implemented at scale. *International Journal of Obesity*, 38 (10)**:** 1343-1349.

Finegood, D. T., T. D. N. Merth and H. Rutter (2010). Implications of the Foresight Obesity System Map for solutions to childhood obesity. *Obesity*, 18 (Supplement 1)**:** S13-S16.

Flegal, K. M., C. L. Ogden, J. A. Yanovski, *et al.* (2010). High adiposity and high body mass index-for-age in US children and adolescents overall and by race-ethnic group. *American Journal of Clinical Nutrition*, 91 (4)**:** 1020-1026.

Flegal, K. M. and J. P. A. Ioannidis (2017). A meta-analysis but not a systematic review**:** An evaluation of the Global *BMI* Mortality Collaboration. *Journal of Clinical Epidemiology*, published on line**:** April 20, 2017, doi**:** 10.1016/j.jclinepi. 2017.04.007

Gobte, N. J. and D. J. Meyer (2018). Back to basics**:** Accurate weight measurements — a key to obesity research in Cameroon. *African Journal of Midwifery and Women's Health*, 12 (3)**:** 145-151

Golan, M. and A. Weizman (2001). Familial approach to the treatment of childhood obesity**:** Conceptual model. *Journal of Nutrition Education*, 33 (2)**:** 102-107

Greydanus, D. E., M. Agana, M. M. Kamboj, *et al.*. (2018). Pediatric obesity**:** Current concepts. *Disease-a-Month*, 64 (4)**:** 98-156.

Hardy, L. L., S. Mihrshahi, J. Gale, B. A. Drayton, A. Bauman and J. Mitchell (2017). 30-year trends in overweight, obesity and waist-to-height ratio by socioeconomic status in Australian children, 1985 to 2015. *International Journal of Obesity*, 41 (1)**:** 76-82.

Holmgren, A., A. Niklasson, A. F. M. Nierop, *et al.* (2017). Pubertal height gain is inversely related to peak BMI in childhood. *Clinical Investigation*, 81 (3)**:** 448-454.

Jaarsveld, C. H. M. and M. C. Gulliford (2015). Childhood obesity trends from primary care electronic health records in England between 1994 and 2013. *Archives of Diseases of Children*, 100 (3)**:** 214-219.

Jamil, N. (2009). Adult-height and adult-weight formulae for the Pakistani population. *MPhil Thesis*, University of Karachi, Karachi, Pakistan (unpublished)

Jamil, S. S. (2014). A method to generate Growth-and-Obesity Profiles of children of still-growing parents. *MPhil Thesis*, FUUAST, Karachi, Pakistan (unpublished)

Kamal, S. A. (2010, March 22). Mathematics in the life sciences. *The First National Conference on Mathematical Sciences*, Golden Jubilee Celebration, Department of Mathematics, University of Karachi, Karachi, Pakistan, p. 19. (the Syed Firdous memorial lecture), abstract#10**:** http://www.ngds-ku.org/Presentations/Firdous.pdf

Kamal, S. A. (2014, May 17). Sports and anthromathematics. *The Fifty-Fifth Annual Prize Distribution Function*, Government College, Hyderabad, Pakistan (seminar)**,** abstract**:**

http://www.ngds-ku.org/Presentations/Sport_Mathematics.pdf

Additional File — Basic and Innovative Concepts in Anthromathematics and Sport Mathematics**:**

http://www.ngds-ku.org/Presentations/Sport_Mathematics/Additional_File.pdf

Clinical examples of 'true-loss of mass', p. 10; 'pseudo-gain of height', p. 11; 'pseudo-gain of mass', p. 12.

Kamal, S. A. (2015*a*). Acute malnutrition in a child suffering from cardiac problems. *International Journal of Biology and Biotechnology*, 12 (4)**:** 585-600, full text**:** http://www.ngds-ku.org/Papers/J40.pdf

Kamal, S. A. (2015*b*). Optimal-mass management in obese children. *International Journal of Biology and Biotechnology*, 12 (3)**:** 381-391, full text**:** http://www.ngds-ku.org/Papers/J38.pdf

Kamal, S. A. (2016*a*, April 7). *Manual for Obtaining Anthropometric Measurements*. University of Karachi, Karachi, Pakistan, version 9.11, full text**:** http://www.ngds-ku.org/ngds_folder/M02.pdf

Step-by-step procedures illustrated through labeled photographs**:**

http://www.ngds-ku.org/Papers/J49/Additional_File_2.pdf

Kamal, S. A. (2016*b*, November 14). Streamlining various definitions of childhood obesity. *Nutrition and Health for Better Living (seminar on the occasion of the World Diabetes Day)*, the University Scholars Forum, University of Karachi, Karachi, Pakistan (concluding talk), p. 1, abstract**:**

http://www.ngds-ku.org/Presentations/Childhood-Obesity-Definitions.pdf

Kamal, S. A. (2017*a*). A series of 5 videos on 'Anthropometry of Children'**:**
First Video — Introduction to Anthropometry of Children**:** https://youtu.be/sXGGaM73S3E
Second Video — Preliminaries**:** https://youtu.be/GxnEowK0AcE
Third Video — Measurement of Height of Children**:** https://youtu.be/l1xs-xkhiBk
Fourth Video — Measurement of Mass of Children**:** https://youtu.be/q916pgYCiC8
Fifth Video — Measurement of MUAC of Children**:** https://youtu.be/O6pr7wfgA_0

Kamal, S. A. (2017*b*). In search of a definition of childhood obesity. *International Journal of Biology and Biotechnology*, 14 (1)**:** 49-67 — Z. H. Z.'s case described in Table A4*b*, p. 64; Z. J.'s case described in Table A5*a*, p. 66, full text**:** http://www.ngds-ku.org/Papers/J45.pdf

Kamal, S. A. (2017*c*). Integration of *BMI*-based-optimal mass and height-percentile-based-optimal mass to propose the sixth-generation solution of childhood obesity. *International Journal of Biology and Biotechnology*, 14 (4)**:** 485-502, full text**:** http://www.ngds-ku.org/Papers/J49.pdf
Additional File 1 — Compliance with Ethical and Human-Right Standards**:** http://www.ngds-ku.org/Papers/J49/Additional_File_1.pdf
Additional File 2 — Height, mass and MUAC measurements (step-by-step procedures illustrated through labeled photographs)**:** http://www.ngds-ku.org/Papers/J49/Additional_File_2.pdf

Kamal, S. A. (2018). Solar-eclipse observations in Pakistan**:** Health and safety perspectives. *The Sky — IJPEHSAS*, 2**:** 38-45, full text**:** http://www.ngds-ku.org/Papers/J51.pdf

Kamal, S. A., A. A. Naz and S. A. Ansari (2016*a*). Growth-and-Obesity Vector-Roadmaps of the Pakistani children. *International Journal of Biology and Biotechnology*, 13 (4)**:** 651-671, full text**:** http://www.ngds-ku.org/Papers/J43.pdf

Kamal, S. A., A. A. Naz and S. A. Ansari (2017*a*). Possible validation of mathematical definition of childhood obesity based on anthropometric data collected during 1998-2013. *International Journal of Biology and Biotechnology*, 14 (2)**:** 219-235 67, full text**:** http://www.ngds-ku.org/Papers/J46.pdf

Kamal, S. A., A. A. Naz, S. Musafar and S. A. Ansari (2016*b*, February 12, 13). Growth-and-Obesity Vector-Roadmaps using enhanced anthropometric instruments**:** The fourth-generation solution of childhood obesity. *The Karachi Phy-sics Society First National Conference on Multidisciplinary Topics in Physics*, Department of Physics, University of Karachi, Karachi, Pakistan, p. 56 (invited lecture), abstract#IT-04**:** http://www.ngds-ku.org/Presentations/Vector.pdf

Kamal, S. A., C. M. S. Manzoor and S. A. Khan (2013*a*, September 4, 5). Diet-based intervemtions and vitamin-D deficiency. *The First Conference on Anthromathematics in the Memory of (Late) Syed Firdous (ANTHROMATHE-MATICS 2013)*, Department of Mathematics, University of Karachi, Karachi, Pakistan and Government College, Hyderabad, Pakistan, p. 14, abstract# Anthro13-08**:** http://www.ngds-ku.org/Presentations/VitaminD.pdf

Kamal, S. A., C. M. S. Manzoor and S. A. Khan (2013*b*, September 4, 5). Increasing height through diet, exercise and life-style adjustment. *The First Conference on Anthromathematics in the Memory of (Late) Syed Firdous (ANTHROMATHE-MATICS 2013)*, Department of Mathematics, University of Karachi, Karachi, Pakistan and Government College, Hyderabad, Pakistan, p. 18, abstract# Anthro13-12**:** http://www.ngds-ku.org/Presentations/Height_Management.pdf

Kamal, S. A., H. I. Azeemi and S. R. Khan (2017*b*). Psychological testing, physical examination and fitness testing of primary-school students for participation in gymnastic activities. *Pumukkale Journal of Sport Sciences*, 8 (2)**:** 15-40 — Table 4 connects Tanner scores with prepubertal, peripubertal, pubertal, adolescent and adult stages of puberty; L. G.'s case described in Table 8*c*, p. 33, full text**:** http://www.ngds-ku.org/Papers/J48.pdf

Kamal, S. A., M. K. Rajput and S. A. Ansari (2016*c*). Gait analysis of 7-10-*year*-old children of Karachi from nutritional-status perspective. *International Journal of Biology and Biotechnology*, 13 (1)**:** 13-25, full text**:** http://www.ngds-ku.org/Papers/J41.pdf

Kamal, S. A., N. Jamil and S. A. Khan (2011). Growth-and-Obesity Profiles of children of Karachi using box-interpolation method. *International Journal of Biology and Biotechnology*, 8 (1)**:** 87-96, full text**:** http://www.ngds-ku.org/Papers/J29.pdf

Kamal, S. A., S. A. Ansari, M. Sarwar and A. A. Naz (2017*c*). Medical criteria for induction into the Armed Forces of Pakistan**:** Cutoff heights for still-growing youth. *International Journal of Biology and Biotechnology*, 14 (3)**:** 319-331, full text**:** http://www.ngds-ku.org/Papers/J47.pdf

Kamal, S. A., S. A. Ansari and S. S. Jamil (2014*a*, September 4). Growth-and-Obesity Enhanced-Roadmaps of children. *The Second Conference on Anthromathematics and Sport Mathematics in the Memory of (Late) Hussain Ahmed Bilgirami (ANTHROMATHEMATICS 2014)*, Department of Mathematics, University of Karachi, Karachi, Pakistan and Government College, Hyderabad, Pakistan, p. 10 (concluding talk), abstract#Anthro14-06**:** http://www.ngds-ku.org/Presentations/Enhanced.pdf

Kamal, S. A., S. A. Ansari and S. S. Jamil (2015). Generating and validating Growth-and-Obesity Roadmaps for the Pakistani children. *International Journal of Biology and Biotechnology*, 12 (1)**:** 47-61, full text**:** http://www.ngds-ku.org/Papers/J35.pdf

Kamal, S. A. and S. A. Khan (2013, September 4, 5). Fitness for primary-school children. *The First Conference on Anthromathematics in the Memory of (Late) Syed Firdous (ANTHROMATHEMATICS 2013)*, Department of Mathematics, University of Karachi, Karachi, Pakistan and Government College, Hyderabad, Pakistan, p. 24, abstract# Anthro13-18**:** http://www.ngds-ku.org/Presentations/Fitness.pdf

Kamal, S. A. and S. A. Khan (2014). Primary-physical-education practices in Pakistan and England**:** Health and safety perspectives. *International Journal of Biology and Biotechnology*, 11 (2&3)**:** 401-419, full text: http://www.ngds-ku.org/Papers/J33.pdf

Kamal, S. A. and S. A. Khan (2015). Hairstyle, footwear and clothing for gymnastic activities in the primary-school setting. *Pumukkale Journal of Sport Sciences*, 6 (3)**:** 46-64, full text**:** http://www.ngds-ku.org/Papers/J37.pdf

Kamal, S. A. and S. A. Khan (2018). Overcoming vitamin-D deficiency in male gymnasts during preteen years. *The Sky — IJPEHSAS*, 2**:** 60-75, full text**:** http://www.ngds-ku.org/Papers/J50.pdf

Kamal S. A., S. Burki and S. S. Jamil (2013*c*, September 4, 5). Optimal-weight management through diet, exercise and lifestyle adjustment. *The First Conference on Anthromathematics in the Memory of (Late) Syed Firdous (ANTHROMATHEMATICS 2013)*, Department of Mathematics, University of Karachi, Karachi, Pakistan and Government College, Hyderabad, Pakistan, p. 9, abstract#Anthro13-03**:** http://www.ngds-ku.org/Presentations/Optimal_Weight.pdf

Kamal, S. A. and S. Firdous (2002*a*, February 14-17). The NGDS Pilot Project**:** Anthropometry of the Pakistani children. *The 16th International Biennial Conference of the Pakistan Pediatric Association*, Karachi, Pakistan, p. 127 (poster presentation), abstract#PO-26**:** http://www.ngds-ku.org/pub/confabst.htm#C48:

Kamal, S. A. and S. Firdous (2002*b*, February 14-17). The NGDS Pilot Project**:** Modeling growth of the Pakistani child-ren. *The 16th International Biennial Conference of the Pakistan Pediatric Association*, Karachi, Pakistan, abstract**:** http://www.ngds-ku.org/pub/confabst.htm#C47:

Kamal, S. A., S. Firdous and S. J. Alam (2004). An investigation of growth profiles of the Pakistani children. *International Journal of Biology and Biotechnology*, 1 (4)**:** 707-717, full text**:** http://www.ngds-ku.org/Papers/J26.pdf

Kamal, S. A., S. J. Alam and S. Firdous (2002, June 22). The NGDS Pilot Project**:** A software to analyze growth of a child (a telemedicine perspective). *The National Telemedicine Conference Pakistan 2002*, Technology Resource Mobiliza-tion Unit (TreMU), Ministry of Science and Technology, Government of Pakistan, Islamabad, Pakistan, p. 2, full text**:** http://www.ngds-ku.org/Papers/C52.pdf

Kamal, S. A. and S. S. Jamil (2012). A method to generate Growth-and-Obesity Profiles of children of still-growing parents. *International Journal of Biology and Biotechnology*, 9 (3)**:** 233-255, full text**:** http://www.ngds-ku.org/Papers/J30.pdf

Kamal, S. A. and S. S. Jamil (2014). KJ-regression model to evaluate optimal masses of extreme cases. *International Jour-nal of Biology and Biotechnology*, 11 (4)**:** 623-648, full text**:** http://www.ngds-ku.org/Papers/J34.pdf
Additional File 3**:** http://www.ngds-ku.org/Papers/J34/Additional_File_3.pdf

Kamal, S. A., S. S. Jamil and S. A. Ansari (2013*d*, September 4, 5). Growth-and-Obesity Roadmaps of children. *The First Conference on Anthromathematics in the Memory of (Late) Syed Firdous (ANTHROMATHEMATICS 2013)*, Department of Mathematics, University of Karachi, Karachi, Pakistan and Government College, Hyderabad, Pakistan, p. 8, abstract#Anthro13-02**:** http://www.ngds-ku.org/Presentations/Roadmap.pdf

Kamal, S. A., S. S. Jamil and U. A. Razzaq (2014*b*). Stunting induced by wasting — Wasting induced by stunting**:** A case study. *International Journal of Biology and Biotechnology*, 11 (1)**:** 147-153, full text**:** http://www.ngds-ku.org/Papers/J32.pdf

Kamal, S. A., U. A. Razzaq and S. S. Jamil (2013*e*, September 4, 5). Importance of standardization of anthropometric measurements. *The First Conference on Anthromathematics in the Memory of (Late) Syed Firdous (ANTHROMATHEMATICS 2013)*, Department of Mathematics, University of Karachi, Karachi, Pakistan and Government College, Hyderabad, Pakistan, p. 12, abstract#Anthro13-06**:** http://www.ngds-ku.org/Presentations/Anthropometry.pdf

Karlberg, J. (1987). Modeling of human growth. *PhD Dissertation*, University of Göteborg, Göteborg, Sweden

Kato, N., T. Isojima, S. Yokota, *et al.* (2018). Earlier *BMI* rebound and lower pre-rebound *BMI* as risk of obesity among Japanese preschool children. *International Journal of Obesity*, 42 (1)**:** 52-58.

Keys, A., F. Fidanza, M. J. Karvonen, N. Kimura and H. L. Taylor (1972). Indices of relative weight and adiposity. *Journal of Chronic Diseases*, 25 (6&7)**:** 329-343.

Kolotourou, M., D. Radley, P. Chadwick, *et al.* (2013). Is *BMI* alone a sufficient outcome to evaluate interventions for childhood obesity? *Childhood Obesity*, 9 (4)**:** 350-356.

Kumar, S. and A. S. Kelly (2018). Review of childhood obesity**:** from epidemiology, etiology, and comorbidities to clinical assessment and treatment. *Mayo Clinic Proceedings*, 92 (2)**:** 251-265.

Mazik, W., K. D. Ward and M. B. Stockton (2007). Childhood obesity**:** Are we missing the big picture? *Obesity Reviews*, 9 (1)**:** 35-42.

Meldrum, D. R., M. A. Morris and J. C. Gambone (2017). Obesity pendanic**:** Causes, conseqiuences and solutions — But do we have the will? *Fertility and Sterility*, 107 (4)**:** 833-839.

Natale, R. A, S. E. Messiah, L. Asfour, S. B. Uhlhorn, A. Delamater and K. L. Arheart (2014). Role modeling as an early childhood obesity prevention strategy: Effect of parents and teachers on preschool children's healthy lifestyle habits. *Journal of Developmental and Behavioral Pediatrics*, 35 (6)**:** 378-387.

Naz, A. A. (2017). Growth-and-Obesity Vector-Roadmaps for the Pakistani children. *PhD Dissertation*, University of Karachi, Karachi, Pakistan (unpublished)

Ogden, C. L., M. D. Carroll, B. K. Kit and K. M. Flagel (2014). Prevalence of childhood and adult obesity in the United States, 2011-2012. *Journal of the American Medical Association*, 311 (8)**:** 806-814.

Ogden, C. L., M. D. Carroll, H. G. Lawman, *et al.* (2016). Trends in obesity prevalence among children and adolescents in the United States, 1988-1994 through 2013-2014. *Journal of the American Medical Association*, 315 (21)**:** 2292-2299.

Parkinson, J., C. Dubelaar, J. Carins, S. Holden, F. Newton and M. Pescud (2017). Approaching the wicked problem of childhood obesity**:** An introduction to the food system compass. *Journal of Social Marketing*, 7 (4)**:** 387-404

Perry, R. A., L. Daniels, L. A. Baur and A. Magarey (2018, September 17). Impact of a 6-*month* family-based weight management programme on child food activity. *Pediatric Obesity*, published online**:** https://doi.org/10.1111/ijpo.12460

Poskitt, E. M. E. (1995). Defining childhood obesity**:** The relative body mass index (*BMI*). *Acta Paediatrica*, 84 (8)**:** 961-963.

Poskitt, E. M. E. (2000). Body mass index and child obesity**:** Are we nearing a definition? *Acta Paediatrica*, 89 (5)**:** 507-509.

Poskitt, E. M. E. (2001). Defining childhood obesity**:** Fiddling whilst Rome burns? *Acta Paediatrica*, 90 (12)**:** 1361, 1362.

Poskitt, E. M. E. (2005). Tracking childhood obesity**:** Diet, physical activity or lifestyle change? *Acta Paediatrica*, 94 (4)**:** 396-398.

Robinson, T. N. and J. R. Sirard (2005). Preventing childhood obesity**:** A solution-oriented research paradigm. *American Journal of Preventive Medicine*, 28 (2S2)**:** 194-201.

Rolland-Cachera, M. F. (2011). Child obesity**:** Current definitions and recommendations for their use. *International Jour-nal of Pediatric Obesity*, 6 (5&6)**:** 325-331.

Rutter, T. (2012). The single most important intervention to tackle obesity. *International Journal of Public Health*, 57 (4)**:** 657, 658.

Saldaña-Tejeda, A. (2018). Mother's experiences of masculinity in the context of child obesity in Mexico. *Women's Studies International Forum*, 70**:** 39-45.

Skinner, A. C. and J. A. Skelton (2014). Prevalence and trends in obesity and severe obesity among children in the United States, 1999-2012. *JAMA Pediatrics*, 168 (6)**:** 561-566.

Tanner, J. M., H. Goldstein and R. H. Whitehouse (1970). Standards for children's height at ages 2-9 years allowing for height of parents. *Archives of Diseases of Children*, 45 (244): 755-762.

Wabitsch, M. (2000). Overweight and obesity in European children: Definition and diagnostic procedures, risk factors and consequences for later health outcome. *European Journal of Pediatrics*, 159 (Supplement 1)**:** S8-S13.

Whittaker, R. C., J. A. Wright, M. S. Pepe, K. D. Seidel and W. H. Dietz (1997). Predicting obesity in young adulthood from childhood and parental obesity. *New England Journal of Medicine*, 337 (13)**:** 869-873.

Wickramasinghe, V. P. (2018). Childhood obesity**:** Socio-cultural determinants. *Sri Lanka Journal of Child Health*, 47 (3)**:** 193-203. (Dr. Stella de Silva memorial oration 2017)

Wieting, J. M. (2008). Cause and effect in childhood obesity**:** Solutions for a national epidemic. *The Journal of the Ameri-can Osteopathic Association*, 108 (10)**:** 545-552,

Zylke, J. W. and H. Buchner (2018). Preventing obesity in children**:** A glimmer of hope. *Journal of the American Medical Association*, 320 (5)**:** 443-444.

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