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# GENERATING AND VALIDATING GROWTH-AND-OBESITY ROADMAPS FOR THE PAKISTANI CHILDREN[¶]

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## ABSTRACT

'Growth-and-Obesity Profiles' of a family gave percentiles of height, mass, optimal mass and status, indicating obesity or wasting as percentage, for all family members. Additionally, for children, target height, current-age-mid-parental height and status, indicating tallness or stunting as percentage, were calculated. To compute parents' obesity profiles, gender-specific heights and masses were used to interpolate respective percentiles using age-20 values. Either parent was suggested to gain mass, if optimal mass exceeded actual mass. In case, value of optimal mass was lesser than actual mass, father was advised to reduce mass corresponding to that difference, provided the value was less than 10 *kilograms*, otherwise he should shed off 10 *kilograms* within the next 6 *months*. For mothers, currently married or recently divorced/widowed, the recommended suggestion to lose mass was computed by adding 5 *kilograms* to their mass, to account for possible pregnancy and the associated fetal mass. Up to the age of 30 *years*, optimal mass was taken as the mass corresponding to height percentile. For individuals older than 30 *years*, body-mass index (*BMI*) was considered to be the reference, computed by dividing mass in *kilograms* by square of height in *meters*. Optimal mass was determined by multiplying square of height with the ideal *BMI* value (24 $kilogram/meter^2$). Linear interpolation was employed to compute target-height percentile. Box interpolation was used to determine child's height/mass percentiles. A comparison of optimal mass with actual mass determined whether the child was wasted or obese. A similar procedure was adopted to compute current-age-mid-parental height. Comparison of child's height with gender-specific-mid-parental height at current age, indicated whether the child was tall or stunted. When more than one profile (each profile representing a checkup) was available, 'Growth-and-Obesity Roadmap' was generated. This roadmap included month-wise recommendations to pick up height and put on or lose mass (weight). These recommendations were generated from the most-recent profile, in such a way that a child was not required to lose more than 10 *kilograms* within the next 6 *months*, in order to avoid any adverse health effects from a rapid loss of mass.

**Keywords:** Optimal mass, wasting, stunting, tallness, estimated-adult BMI, energy channelization

## LIST OF ABBREVIATIONS

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

**BLA:** **B**eacon **L**ight **A**cademy, Gulshan-é-Iqbal, Karachi
**BMI:** **B**ody-**M**ass **I**ndex
**MP:** **M**id-**P**arental
**NGDS:** **N**ational **G**rowth and **D**evelopmental **S**tandards for the Pakistani Children
**SF:** The **S**yed **F**irdous Growth-and-Imaging Laboratory, University of Karachi
**SGPP:** **S**ibling **G**rowth **P**ilot **P**roject — a subproject of the NGDS Pilot Project
**WHO:** **W**orld **H**ealth **O**rganization

## INTRODUCTION

One of the areas, which is of prime concern in the current civilization is the maintenance of proper weight-for-height (Mozaffarain *et al.*, 2011), which acts as deterrent to many diseases (Ludwig, 2007) and ensures a better body image in teenagers (Lee *et al.*, 2013). Life expectancy is reduced by presence of obesity during childhood and adolescence (Fontaine *et al.*, 2003). On the other hand, wasting is shown to be related to, not only, depression at the individual level, but also, suicidal rates at the population level (Barker *et al.*, 1995). Communities, worldwide, have considered it a health priority to measure heights and weights of children to determine prevalence of obesity (Wilkand *et al.*, 2002; Barthel *et al.*, 2001) and maintain updated growth charts (Karlberg *et al.*, 1999). However, very few studies of this sort have been done in Pakistan. Some recent work by local researchers, *e. g.*, Ramzan *et al.* (2008), Aziz *et al.* (2012) and Mushtaq *et al.* (2012) is worth mentioning.

The WHO Child Growth Standards, released in 2006, depict normal growth under optimal environmental conditions and can be used, universally, to evaluate children. These standards are independent of ethnicity, socioeconomic status and feeding type (WHO Multicentre Growth Reference Study Group, 2006*a*; *b*). De Onis et al. (2012)

[¶]Main contribution of PhD dissertation of the second author, registered from Department of Physics, University of Karachi. The italic superscripts [a], [b], [c], …, appearing in the text, represent endnotes listed before references.

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scrutinized worldwide implementation of the WHO and found that countries have adopted and harmonized best practices in child-growth assessment.

There are issues of defining optimal weight (Cole *et al.*, 2000; Hermanussen and Meigen, 2003) and then devising ways to achieve that (Kamal *et al.*, 2013*d*). Another problem arises, in the absence of reliable growth charts for third-world countries, where researchers have no option, but to use charts from other populations, like NCHS (Ayatollahi, 1993) and sometimes use statistical methods to adjust these charts to local population (Abolfotouh *et al.*, 1993; Al Frayh and Bamgboye, 1993). Some preliminary work has been started by various groups (Kamal *et al.*, 2004; Aziz *et al.*, 2012; Mushtaq *et al.*, 2012).

This work describes a method to generate Growth-and-Obesity Roadmaps of Pakistani children, which is an extension of Growth-and-Obesity Profiles, described in an earlier work (Kamal *et al.*, 2011). The prime contribution of this piece of research is month-wise recommendation to gain height and put on/lose weight based on mathematical calculations. This is very important for the health of a child, as an excess reduction of weight may have adverse effects on the health of a child. On the other hand, if the required amount of weight is not reduced, the child remains obese and all the health risks of obesity apply. Studies have indicated that even a small amount of weight increase in childhood elevates coronary-heart-disease risk factor in adulthood (Baker *et al.*, 2007; Bibbins-Domingo *et al.*, 2007).

## MID-PARENTAL HEIGHT, STUNTING AND TALLNESS

For the purpose of generating growth-and-obesity roadmaps, stunting and tallness were defined by taking mid-parental height as reference. To compute adult-mid-parental (target) height of a boy ($h_{\text{MP-BOY}}$) or a girl ($h_{\text{MP-GIRL}}$) from biological father's height ($F$) and biological mother's height ($M$) using the expressions (1*a*, *b*) — all heights are in *cm* (Chianese, 2005; Karlberg, 1996; Tanner *et al.*, 1970)**:**

(1*a*) $$h_{\text{MP-BOY}} = \frac{F+M}{2} + 6.5\ cm$$

(1*b*) $$h_{\text{MP-GIRL}} = \frac{F+M}{2} - 6.5\,cm$$

Target heights may vary by 5 *cm* on either side. A child was declared to be stunted, when the individual's height percentile, $P(h)$, was lesser than percentile of mid-parental height, $P(h_{\text{MP}})$, as given in (2*a*)**:**

(2*a*) $P(h) < P(h_{\text{MP}})$ or $\Delta h = h - h_{\text{current-age-MP}} < 0$, for a stunted child

For a tall child, the reverse was true, as represented in (2*b*)**:**

(2*b*) $P(h) > P(h_{\text{MP}})$ or $\Delta h = h - h_{\text{current-age-MP}} > 0$, for a tall child

Quantitative estimates of tallness and stunting in terms of percentages (Kamal *et al.*, 2011) were given by taking current-age-mid-parental height as reference, listed in equations (3*a*-*c*).

If $STATUS(h) > 1\%$

(3*a*) $$STATUS(h) = 100\frac{|h - h_{\text{current-age-MP}}|}{h_{\text{current-age-MP}}}\%\ \text{STUNTED, if } h < h_{\text{current-age-MP}}$$

(3*b*) $$STATUS(h) = 100\frac{|h - h_{\text{current-age-MP}}|}{h_{\text{current-age-MP}}}\%\ \text{TALL, if } h > h_{\text{current-age-MP}}$$

Else if $STATUS(h) \le 1\%$

(3*c*) $$STATUS(h) = 100\frac{|h - h_{\text{current-age-MP}}|}{h_{\text{current-age-MP}}}\%(\mp)$$

In equation (3*c*), (–) was taken if $h < h_{\text{current-age-MP}}$ and (+) if $h > h_{\text{current-age-MP}}$. This was the normal range, indicating that the child had excess (lesser) height compared with current-age-mid-parental height. However, the individual was not considered stunted or tall.

Excessive stunting may be indicative of acute malnutrition, if associated with wasting, or energy-channelization problem, if accompanied by obesity. Excessive tallness may suggest over-nutrition, if associated with obesity, or

| | |
|---|---|
| **4th-Degree Stunted** | $STATUS_{\pm}(h) < -30$ |
| **3rd-Degree Stunted** | $-30\% \le STATUS_{\pm}(h) < -20\%$ |
| **2nd-Degree Stunted** | $-20\% \le STATUS_{\pm}(h) < -10\%$ |
| **1st-Degree Stunted** | $-10\% \le STATUS_{\pm}(h) < -1\%$ |
| **Normal** | $-1\% \le STATUS_{\pm}(h) < +1\%$ |
| **1st-Degree Tall** | $+1\% \le STATUS_{\pm}(h) < +10\%$ |
| **2nd-Degree Tall** | $+10\% \le STATUS_{\pm}(h) < +20\%$ |
| **3rd-Degree Tall** | $+20\% \le STATUS_{\pm}(h) < +30\%$ |
| **4th-Degree Tall** | $STATUS_{\pm}(h) \ge +30\%$ |

Fig. 1. Suggested classification and color-coding for status (pertaining-to-height) expressed as percentage (http://www.ngds-ku.org/Papers/J35/Fig_1.htm)

energy-channelization problem, if accompanied by wasting (Kamal and Jamil, 2014). The last condition, also, poses health risks, in particular, scoliosis (Kamal *et al.*, 2013*c*).

Use of absolute value in the formulae for *STATUS*(*h*) poses some mathematical problems. The function, defined by equations (3*a*, *b*) is continuous, but not differentiable. Hence, this function cannot be processed using mathematical and computational tools, in particular, when there is a need to compute rates of change. A similar problem arose in discarding the use of mean deviation in favor of standard deviation for the purpose of statistical analysis. A moment-generating function could not be written for the former. This was the basis of selecting sample size large enough so that the assumption that the data are normally distributed is valid. Abandoning modulus sign and admitting both positive (indicating tallness) and negative (indicating stunting) values, would make the above function a true algebraic function and it would become natural to plot it on number line of a graph paper. A definition of algebraic status (pertaining-to-height) is given in equation (4).

(4) $$STATUS_{\pm}(h) = 100\frac{h - h_{\text{current-age-MP}}}{h_{\text{current-age-MP}}}\%$$

A classification of tallness and stunting, suggested by the authors, is given in Figure 1.

## BODY-MASS INDEX (*BMI*)

In 1832, Adolphe Quetelet proposed this index, recognized by peers as ‘Quetelet Index’ (Eknoyan, 2008), renamed later as ‘Body-Mass Index’ (Keys *et al.*, 1972). Apell *et al.* (2011) discussed physics of body-mass index (*BMI*). *BMI* of a person is computed by dividing mass, $\mu$, of an individual (in *kg*) by square of height of that person, *h* (in *m*) and is expressed in $kg/m^2$ — *cf*. equation (5)

(5) $$BMI = \frac{\mu}{h^2}$$

Table 1 gives *BMI* classification for adults. The authors replaced the terminologies ‘underweight’ and ‘overweight’ with ‘wasted’ and ‘obese’ preceded by appropriate adjectives, to indicate severity. For children, *BMI* range, used for estimating statuses for adults, cannot be used — *BMI* tables are needed for interpretation (Kamal *et al.*, 2013*d*).

Table 1. WHO classification[a] of body-mass index, applicable to adult population

| *Descriptive Label* | *BMI Values* |
|---|---|
| Excessively Wasted | $BMI < 15$ |
| Severely Wasted | $15 \le BMI < 16$ |
| Wasted | $16 \le BMI < 18.5$. |
| Normal | $18.5 \le BMI < 25$ |
| Obese | $25 \le BMI < 30$ |
| Moderately Obese | $30 \le BMI < 35$ |
| Severely Obese | $35 \le BMI < 40$ |
| Excessively Obese | $BMI \ge 40$ |

**ESTIMATED-ADULT BMI**

Introduced in 2012, equation (6) could be used to compute 'estimated-adult *BMI*' by substituting mass and height of a growing boy or girl by the respective estimated-adult values[b], $\mu_{\text{est-adult}}$ and $h_{\text{est-adult}}$, which provided a snapshot of status of obesity of children, when they reach adulthood — boys at the age of 21 *years* and girls 19 *years* (Kamal and Jamil, 2012).

(6) $$BMI_{\text{est-adult}} = \frac{\mu_{\text{est-adult}}}{(h_{\text{est-adult}})^2}$$

$BMI_{\text{est-adult}}$ could be interpreted on the basis of Table 1.

**OPTIMAL MASS (WEIGHT), WASTING AND OBESITY**

The term 'optimal mass' was, first, mentioned 10-*year* ago (Kamal *et al.*, 2004), with rigorous definition provided 3-*year* ago as the mass, $\mu_{\text{opt}}$, corresponding to height percentile (Kamal *et al.*, 2011). If $P(\mu_{\text{opt}})$ and $P(h)$ represented percentiles of optimal mass and height, respectively, then these percentiles were related by equation (7)

(7) $$P(\mu_{\text{opt}}) = P(h)$$

For the purpose of generating growth-and-obesity roadmaps, if the mass of an individual was lesser than optimal mass, then the incumbent was wasted; whereas if it was more than optimal mass, it represented obesity, according to the inequalities (8*a*, *b*)

(8*a*) $\Delta\mu = \mu - \mu_{\text{opt}} < 0$ or $P(\mu) < P(h)$, for a wasted child

(8*b*) $\Delta\mu = \mu - \mu_{\text{opt}} > 0$ or $P(\mu) > P(h)$, for an obese child

Quantitative estimates of wasting and obesity were given in equation (9*a*, *b*) by taking optimal mass as reference (Kamal *et al.*, 2011).

If $STATUS(\mu) > 1\%$

(9*a*) $$STATUS(\mu) = 100\frac{|\mu - \mu_{\text{opt}}|}{\mu_{\text{opt}}}\%\ \text{WASTED, if } \mu < \mu_{\text{opt}}$$

(9*b*) $$STATUS(\mu) = 100\frac{|\mu - \mu_{\text{opt}}|}{\mu_{\text{opt}}}\%\ \text{OBESE, if } \mu > \mu_{\text{opt}}$$

Else if $STATUS(\mu) \le 1\%$

(9*c*) $$STATUS(\mu) = 100\frac{|\mu - \mu_{\text{opt}}|}{\mu_{\text{opt}}}\%(\mp)$$

In equation (9*c*), (–) was taken if $\mu < \mu_{\text{opt}}$ and (+) if $\mu > \mu_{\text{opt}}$. This was the normal range, indicating that the child had excess (lesser) mass compared with optimal mass. However, the individual was not considered wasted or obese.

Both excessive obesity and wasting are associated with health risks. Excessive obesity may be indicative of over-nutrition, if associated with tallness, or energy-channelization problem, if accompanied by stunting. Childhood obesity has been declared epidemic by the US First Lady, Michelle Obama (S. Z. Yanovski and J. A. Yanovski, 2011). According to Ludwig (2007), obesity in children is associated with cardiovascular, gastrointestinal, musculo-skeletal, neurological, psychosocial, pulmonary and renal problems. He classified into 4 phases the long-term effects of obesity epidemic. Phase I, from 1970 till 2007, exhibited increasing cases of obesity due to lack of awareness of its adverse effects. Phase II emerged in the following years with serious medical conditions, such as type-II diabetes, fatty lever and many psychosocial problems. In Phase III, the situation, further, worsened and life-threatening diseases, like coronary heart disease, kidney failure *etc.* increased mortality rate and shortened life expectancy of American population. In Phase IV, the prevalence of weight-related diseases would accelerate more resulting in non-genetic influences in the offspring, if this trend continues. In an e-communication to one of our group members, Ludwig explained: "Phase IV of the epidemic would develop slowing over time, as obese children grow up and give birth to the next generation of children" (Kamal and Jamil, 2012). Excessive wasting may be indicative of under-

| | |
|---|---|
| **4th-Degree Wasted** | $STATUS_{\pm}(\mu) < -30$ |
| **3rd-Degree Wasted** | $-30\% \leq STATUS_{\pm}(\mu) < -20\%$ |
| **2nd-Degree Wasted** | $-20\% \leq STATUS_{\pm}(\mu) < -10\%$ |
| **1st-Degree Wasted** | $-10\% \leq STATUS_{\pm}(\mu) < -1\%$ |
| **Normal** | $-1\% \leq STATUS_{\pm}(\mu) < +1\%$ |
| **1st-Degree Obese** | $+1\% \leq STATUS_{\pm}(\mu) < +10\%$ |
| **2nd-Degree Obese** | $+10\% \leq STATUS_{\pm}(\mu) < +20\%$ |
| **3rd-Degree Obese** | $+20\% \leq STATUS_{\pm}(\mu) < +30\%$ |
| **4th-Degree Obese** | $STATUS_{\pm}(\mu) \geq +30\%$ |

Fig. 2. Suggested classification and color-coding for status (pertaining-to-mass) expressed as percentage (http://www.ngds-ku.org/Papers/J35/Fig_2.htm)

nutrition, if associated with stunting, or energy-channelization problem, if accompanied by tallness (Kamal and Jamil, 2014).

The arguments, which motivated the authors to introduce $STATUS_{\pm}(h)$ are, equally, applicable to define algebraic status (pertaining-to-mass), admitting both positive (indicating obesity) and negative (indicating wasting) values, through equation (10)

$$STATUS_{\pm}(\mu) = 100\frac{\mu - \mu_{\text{opt}}}{\mu_{\text{opt}}}\% \quad (10)$$

A classification of obesity and wasting, suggested by the authors, is given in Figure 2.

## THE NGDS PILOT PROJECT

In 1998, the NGDS Pilot Project (http://ngds.uok.edu.pk) was launched after ‘Institutional Review Process’, which incorporated existing ethical and human-right standards applicable in Pakistan (Kamal *et al.*, 2002; 2004). ‘Opt-in policy’ was implemented by requiring the parents to complete and sign ‘Informed Consent Form’[c]. A subproject of the NGDS Pilot Project, named as SGPP (Sibling Growth Pilot Project), served local families, who reported to SF-Growth-and-Imaging Laboratory for detailed checkup after filling out ‘SGPP Participation Form’[d].

Heights, *h*, and masses of families were measured by reproducible anthropometrists (Kamal and Razzaq, 2014) to accuracies of 0.01 *cm* and 0.01 *kg*, in the morning hours, as per protocols suggested elsewhere (Kamal, 2006, 2010). Parents were measured wearing minimal indoor clothing and the children were required to undress totally except briefs or panties (*cf.* Figure 3). Everyone removed shoes and socks as well as accessories for

Fig. 3. Height and mass of a boy measured in SF-Growth-and-Imaging Laboratory (http://www.ngds-ku.org/Papers/J34/Fig_3.htm)

measurements. A suitable clothing correction was subtracted from 'gross mass' (mass, with the subject wearing indoor clothing) to obtain 'net mass' (mass without any clothing on), $\mu$, for father and mother. Since, the children had to be in underwear for their checkups, barefoot, stripped-to-waist, their recorded masses were, almost, equal to net masses and used without any clothing correction.

For measuring height (stature), the subject was aligned to mounted (engineering) tape and advised to keep hands straight and open, feet together, palms touching thighs and holding breath (attention position). Holding a pencil at eye level, head was straightened. For measuring mass, the subject was asked to stand in the center of beam scale with empty hands and feet separated, looking straight and holding breath (stand-at-ease position). The anthropometrist recorded height to nearest 0.01 *cm* and mass to nearest 0.01 *kg* (Kamal, 2010). Equipments were calibrated using a standard 100-*cm* ruler and a standard 2-*kg* mass. Zero errors were determined before starting each session and subtracted from the measured values.

## A REVIEW OF GROWTH-AND-OBESITY MODELS

### *Correlation Model*

This model was presented by Arglye, Seheult and Wooff 7-*year* ago (Arglye *et al.*, 2007) to statistically process child-growth data.

*Main Contributions*

- Fitted and modeled serial correlation structure of growth measurements of children.
- Eliminated the need of monitoring growth at specific ages.

### *ICP Model*

The ICP (**I**nfancy-**C**hildhood-**P**uberty) Model is a time series, representing analysis of the longitudinal development of human body (Karlberg, 1987; 1996). Height of child (on *y* axis) is plotted as a function of age (on *x* axis). Moment of birth is taken as zero time, whereas zero height is the height at conception. Term of baby is *x* intercept and birth length is *y* intercept. Growth curve is split into 3 separate and partially superimposed components, viz. infancy, childhood and puberty. Infantile period begins before birth and continues up to 3 or 4 *years* of age. This period may be interpreted as postnatal continuation of 'fetal growth'. This model has been described in detail in one of our previous works (Kamal and Jamil, 2012).

*Main Contributions*

- Indicated that height curve is continuous, but not smooth, making height velocity undefined during phase transitions, *i. e.*, infancy-to-childhood phase and childhood-to-puberty phase.
- Gave mathematical expressions to represent height trajectory in infancy, childhood and puberty regions.
- Identified a decrease in growth (height) velocity as the child's age approaches the terminal part of a certain region and about to experience phase transition.

### *KFA Model*

KFA (Kamal-Firdous-Alam) Model assumed that height and mass trajectories were, approximately, linear if the measurements were performed 6-*month* apart — assumption valid for most of the ICP curve (Kamal *et al.*, 2002; 2004). Exceptions were the regions characterized by a rapid growth-rate change — infancy-to-childhood phase and childhood-to-puberty phase. In other regions, linear interpolation was used to compute height at some age grid. Target heights for boys and girls were determined and backward extrapolation performed to evaluate desired heights at reference age grids.

*Main Contributions*

- Compared desired height (based on mid-parental height, extrapolated backward at a certain age grid, which the child has just passed) with interpolated-actual heights to determine if a child was tall or stunted.
- Employed a similar procedure for mass to classify a child as obese or wasted.
- Predicted height and mass 6-*month* down the road.

### *KJR Model*

KJR (Kamal-Jamil-Razzaq) Model (Kamal *et al.*, 2014*b*) was an extension of KFA Model (Kamal *et al.*, 2004). This model generated 'Growth-and-Obesity-Moving Profiles' of children. When these moving profiles were generated for real-time data, these were termed as 'roadmaps' (Kamal *et al.*, 2013*e*; 2014*a*). Numerical examples of

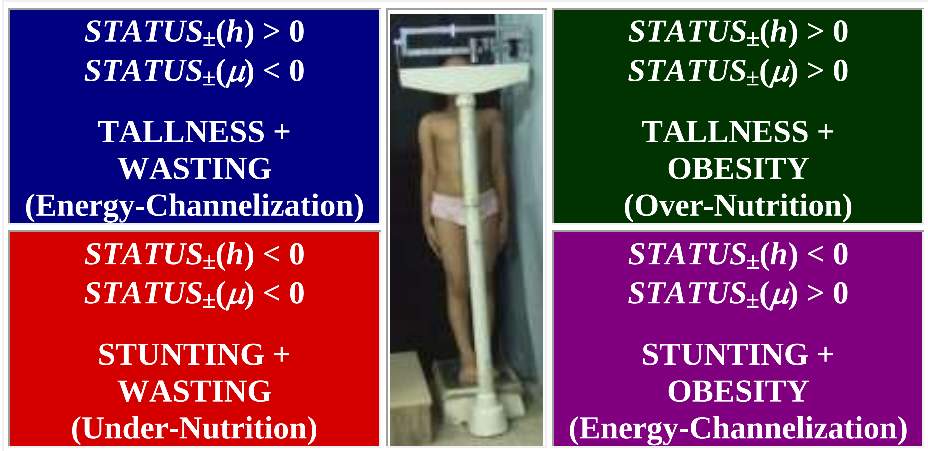



Fig. 4. Energy-channelization (coexistences of tallness and wasting as well as stunting and obesity), under-nutrition (coexistence of stunting and wasting) over-nutrition (coexistence of tallness and obesity) in terms of statuses, pertaining to mass [*x* axis — value increasing from left to right] and height [*y* axis — value increasing from bottom to top] (http://www.ngds-ku.org/Papers/J35/Fig_4.htm)

some of the important concepts introduced alongwith KJR Model (Kamal *et al.*, 2014*b*) and a subsequent seminar (Kamal, 2014*b*) are given elsewhere (Kamal and Jamil, 2014).

*Main Contributions*

- Replaced the concepts of growth (height) velocity and rate of mass gain (loss) by height- and mass-percentile trajectories.
- Introduced the notions of pseudo-gain of mass, pseudo-gain of height, energy-channelization problem (stunting with obesity, wasting with tallness) — *cf.* Figure 4.

***KJK Model***

KJK (Kamal-Jamil-Khan) Model (Kamal *et al.*, 2011) gave procedures to generate ‘Growth-and-Obesity Profiles’ of a family, which consisted of Obesity Profiles of father and mother as well as Growth-and-Obesity Profile of each child based on a single check up.

*Main Contributions*

- Gave a formal definition of ‘optimal mass’, as the mass corresponding to percentile of height.
- Abandoned different terminologies, ‘fat’, ‘overweight’, ‘obese’, ‘lean’, ‘underweight’, ‘wasted’ in favor of ‘obese’ and ‘wasted’.
- Technique of ‘box interpolation’ was developed to compute percentiles of height and mass of child.
- ‘Status (pertaining-to-mass)’ was suggested to indicate severity of obesity or wasting in terms of percentage.
- ‘Status (pertaining-to-height)’ was introduced to give an impression of extent of tallness or stunting in terms of percentage.

***KJ Model***

KJ (Kamal-Jamil) Model presented a mathematical solution of the problem of generating ‘Growth-and-Obesity Profiles’ of children of a family, in which one or both parents were still growing (father’s age below 21 *years*; mother’s age below 19 *years*). Box interpolation was employed to compute percentiles corresponding to father’s and mother’s heights (Kamal and Jamil, 2012).

*Main Contributions*

- ‘Estimated-adult *BMI*’ was introduced, which gave a rough estimate of obesity or stunting, when the child becomes a fully-grown adult.
- Discussed the implications of childhood marriages on the health of mother and her children from psychological and physiological perspectives, taking into consideration points of view of various religious scholars as well as sociological theories.
- Early marriages have, also, been scrutinized from the perspectives of physics, biology and control theory.
- This work tried to elaborate difference between ‘age of puberty’ and ‘age of marriage’.

Table 2*a*. Adult-mid-parental (Target) and army-cutoff heights for S. Family

Father's Height**:** 172.01 *cm* • Mother's Height**:** 162.94 *cm*

| *Adult-Mid-Parental (Target) and Army-Cutoff Heights* | *Boy* | | *Girl* | |
|---|---|---|---|---|
| | *Target* | *Army-Cutoff* | *Target* | *Army-Cutoff* |
| **Case Number** | **SGPP-KHI-20110614-01** | | | |
| Height (*cm*) | 173.98 | 162.56 *cm* | 160.98 | 157.48 *cm* |
| Height (*ft*-*in*) | 5 *ft* 8.49 *in* | 5 *ft* 4.00 *in* | 5 *ft* 3.38 *in* | 5 *ft* 2.00 *in* |
| Percentile | 35.68 | 2.72 | 36.49 | 19.36 |

## GROWTH-AND-OBESITY ROADMAPS

### *Model Development*

*Dates of Birth and Checkups***:** The first step in generating 'Growth-and-Obesity Roadmaps' of a family was conversion of dates of birth and dates of measurement in fractional form and finding difference to compute age. Dates of birth and checkup were recorded as *YYYY-MM-DD* — *year* in four digits-*month* in two digits-*day* in two digits; ages as *YY-MM-DD* (*year* in two digits). Appendix A of (Kamal *et al.*, 2011) gave the detailed procedure.

*Parents' Obesity Profiles***:** To compute Parents' Obesity Profiles, heights and masses, obtained from extended-gender-specific tables (http://www.ngds-ku.org/Papers/J34/Additional_File_3.pdf), were used to interpolate, linearly, percentiles of heights and masses of father and mother using upper bound of age (20 years), for which the anthropometric data were available. These tables contained heights and masses corresponding to $0.01^{th}$, $0.1^{th}$, $1^{st}$, $99^{th}$, $99.9^{th}$ and $99.99^{th}$ percentiles, in addition to values given in CDC Growth Tables (Kamal and Jamil, 2014).

*Parents' Obesity Roadmaps***:** Father (Mother) was advised to put on mass (weight) corresponding to the difference obtained by subtracting net mass from optimal mass, if the value of former was lesser than that of later (weight in *pounds* and *ounces* was obtained using the relations**:** 1 *kg* = 2.205 *lb*; 1 *lb* = 16 *oz*). In case, value of net mass was greater than optimal mass, father was suggested to lose mass corresponding to that difference, provided the value is under-10 *kg*, otherwise he should shed off 10 *kg* within the next 6 *months*. For mothers (married at the time of check up or divorced/widowed in the near past), the recommendation to lose mass was computed by adding 5 *kg* to gross mass, to take care of possible pregnancy and the associated fetal mass. For males and females below or equal to the age of 30 *years*, mass corresponding to their height percentile was considered as optimal mass. For parents older than this age limit, the reference was *BMI* (body-mass index)[e]. To compute optimal mass, square of height was multiplied with the ideal *BMI* value (24 $kg/m^2$). Month-wise recommendations were generated for each parent.

*Children's Growth-and-Obesity Profiles***:** 'Linear interpolation' was used to determine percentiles of target height (adult-mid-parental-height) for son or daughter from age-20-height values. Army-cutoff-height values (5 *ft* 4 *in* for males; 5 *ft* 2 *in* for females), applicable for induction into Pakistani military and paramilitary services, were converted into *cm* (1 *ft* = 12 *in*; 1 *in* = 2.54 *cm*) and respective percentiles computed using 'linear interpolation' (extended table was needed to compute percentile for males, as the value fell below $3^{rd}$ percentile). Tables 2*a*, *b* give target and army-cutoff heights for S. and J. Families, respectively, the eldest sibling of the first family representing 'a wasted child' and that of the second family 'an obese child'. Child's height (mass) percentile was evaluated by the technique of 'box interpolation' (Kamal *et al.*, 2011). Estimated-adult height (mass) was computed using age-20 values. Equation (6) was used to evaluate estimated-adult *BMI*. Constant-age route was followed to compute optimal mass and, subsequently, determine obesity profile. A similar procedure was used to evaluate current-age-mid-parental height. To figure out whether the child was tall or stunted, the incumbent's height was compared with gender-specific-current-age-mid-parental height. Statuses (pertaining-to-height) and (pertaining-to-mass) were computed using equations (4) and (10), alongwith qualitative classifications based on Figures 1 and 2, respectively.

Table 2*b*. Adult-mid-parental (Target) and army-cutoff heights for J. Family

Father's Height**:** 165.70 *cm* • Mother's Height**:** 155.73 *cm*

| *Adult-Mid-Parental (Target) and Army-Cutoff Heights* | *Boy* | | *Girl* | |
|---|---|---|---|---|
| | *Target* | *Army-Cutoff* | *Target* | *Army-Cutoff* |
| **Case Number** | **SGPP-KHI-20060412-01** | | | |
| Height (*cm*) | 167.22 | 162.56 *cm* | 154.22 | 157.48 *cm* |
| Height (*ft*-*in*) | 5 *ft* 8.49 *in* | 5 *ft* 4.00 *in* | 5 *ft* 3.38 *in* | 5 *ft* 2.00 *in* |
| Percentile | 35.68 | 2.72 | 36.49 | 19.36 |

Table 3*a*. Growth-and-Obesity Roadmap of Hr. S. — Eldest sibling of S. Family, exhibiting wasting

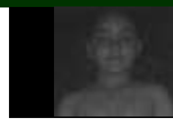
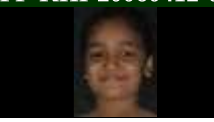
Gender: Female • Date of Birth[f]: 2005-04-10 • School: Withheld • GR Number: Withheld

| *Checkup* | $1^{st}$ | $2^{nd}$ | $3^{rd}$ |
|---|---|---|---|
| **Case Number** | **SGPP-KHI-20110614-01/01 (NGDS-BLA-2011-5085/H)** | | |
| Photograph[g] |  |  |  |
| Larger-Size Photographs: http://www.ngds-ku.org/Papers/J35/Fig_5A.htm | | | |
| Scanned Signatures[g] | *HrS* | *HrS* | *HrS* |
| Class and Section | Withheld | Withheld | Withheld |
| Date of Checkup[f] | 2012-07-15 | 2013-05-15 | 2013-11-21 |
| Age[h] (*year-month-day*) | 07-03-05 | 08-01-05 | 08-07-11 |
| Age (*decimal years*) | 7.26 | 8.10 | 8.62 |
| Dress Code[i] | 0/0.5 | 0/0.5 | 0/0.5 |
| Behavior Code[j] | 1 | 0 | 0 |
| Cumulative-Scoliosis-Risk Weightage[k] | 9.50 | 10.25 | 15.25 |
| Height, *h* (*cm*) | 119.36 | 124.53 | 126.45 |
| Height (*ft-in*) | 3 *ft* 10.99 *in* | 4 *ft* 1.03 *in* | 4 *ft* 1.78 *in* |
| Percentile-for-Height, *P*(*h*) | 24.63 | 27.08 | 23.09 |
| Estimated-Adult Height (*cm*) | 158.87 | 159.33 | 158.46 |
| Estimated-Adult Height (*ft–in*) | 5 *ft* 2.55 *in* | 5 *ft* 2.73 *in* | 5 *ft* 2.39 *in* |
| Current-Age-MP Height (*cm*) | 121.15 | 126.00 | 128.76 |
| Δ Height *w. r. t.* Current-Age-MP (*cm*) | –1.79 | –1.47 | –2.29 |
| Status (pertaining-to-height), $STATUS_{\pm}(h)$ | –1.48% | –1.17% | –1.78% |
| **Qualitative Status (pertaining-to-height)** | **$1^{st}$-Degree Stunted** | **$1^{st}$-Degree Stunted** | **$1^{st}$-Degree Stunted** |
| Current-Age-Army-Cutoff Height (*cm*) | 118.28 | 122.99 | 125.64 |
| Δ Height *w. r. t.* Army-Cutoff (*cm*) | +1.08 | +1.54 | +0.81 |
| Reference Height (*cm*) | 121.15 | 126.00 | 128.76 |
| Percentile-for-Reference-Height | 36.49 | 36.49 | 36.49 |
| Age of Prediction, *A*+ (*years*) | 7.77 | 8.60 | 9.11 |
| Reference Height at *A*+ (*cm*) | 124.14 | 128.67 | 131.23 |
| 6-Month-Height Management (*cm*) | +4.78 | +4.14 | +4.78 |
| **Month-Wise-Height Management (*cm/month*)** | **+0.80** | **+0.69** | **+0.80** |
| Month-Wise-Height Management (*in/month*) | +0.31 | +0.27 | +0.31 |
| Gross Mass (*kg*) | 19.19 | 21.90 | 22.53 |
| Clothing Correction (*kg*) | 0 | 0 | 0 |
| Net Mass, $\mu$ (*kg*) | 19.19 | 21.90 | 22.53 |
| Net Weight (*lb-oz*) | 42 *lb* 5.02 *oz* | 48 *lb* 4.63 *oz* | 49 *lb* 10.86 *oz* |
| Percentile-for-Net-Mass $P(\mu)$ | 8.13 | 14.74 | 10.30 |
| Estimated-Adult Mass (*kg*) | 47.60 | 49.68 | 48.46 |
| Estimated-Adult Weight (*lb–oz*) | 104 *lb* 15.37 *oz* | 109 *lb* 8.67 *oz* | 106 *lb* 13.82 *oz* |
| *BMI*: Body-Mass Index ($kg/m^2$) | 13.47 | 14.12 | 14.09 |
| Estimated-Adult *BMI* ($kg/m^2$) | 18.86 | 19.57 | 19.30 |
| Optimal Mass (*kg*) | 21.15 | 23.47 | 24.39 |
| Δ Mass-for-Height (*kg*) | –1.96 | –1.57 | –1.86 |
| Status (pertaining-to-mass), $STATUS_{\pm}(\mu)$ | –9.28% | –6.68% | –7.61% |
| **Qualitative Status (pertaining-to-mass)** | **$1^{st}$-Degree Wasted** | **$1^{st}$-Degree Wasted** | **$1^{st}$-Degree Wasted** |
| Optimal Mass for Reference Height at *A*+ (*kg*) | 23.57 | 25.98 | 27.64 |
| 6-Month-Mass Management (*kg*) | +4.38 | +4.08 | +5.11 |
| **Month-Wise-Mass Management (*kg/month*)** | **+0.73** | **+0.68** | **+0.85** |
| Month-Wise-Mass Management (*lb-oz/month*) | +1 *lb* 9.75 *oz* | +1 *lb* 8.01 *oz* | +1 *lb* 13.98 *oz* |
| Nutritional Status | Under-Nutrition | Under-Nutrition | Under-Nutrition |

*Children's Growth-and-Obesity Roadmaps*: To construct 'Growth-and-Obesity Roadmaps' of boys or girls (Table 3*a* lists 'Growth-and-Obesity Roadmap' for a wasted child, salient feature of which is month-wise recommen-

Table 3*b*. Growth-and-Obesity Roadmap of Z. J. — Eldest sibling of J. Family, exhibiting obesity

Gender: Female • Date of Birth[f]: 1996-09-23 • School: Withheld • GR Number: Withheld

| *Checkup* | *1st* | *2nd* | *3rd* |
|---|---|---|---|
| **Case Number** | **SGPP-KHI-20060412-01/01** | | |
| Photograph[g] |  |  |  |
| Larger-Size Photographs: http://www.ngds-ku.org/Papers/J35/Fig_5B.htm | | | |
| Scanned Signatures[g] | *ZJ* | *ZJ* | *ZJ* |
| Class and Section | Withheld | Withheld | Withheld |
| Date of Checkup[f] | 2007-05-13 | 2007-10-07 | 2008-06-15 |
| Age[h] (*year-month-day*) | 10-07-20 | 11-00-14 | 11-08-22 |
| Age (*decimal years*) | 10.63 | 11.04 | 11.73 |
| Dress Code[i] | 0/0.5 | 0/0.5 | 0/0.5 |
| Behavior Code[j] | 0 | 0 | 0 |
| Cumulative-Scoliosis-Risk Weightage[k] | 0.50 | 1.00 | 6.00 |
| Height, *h* (*cm*) | 136.41 | 139.70 | 146.53 |
| Height (*ft-in*) | 4 *ft* 5.71 *in* | 4 *ft* 7.00 *in* | 4 *ft* 9.69 *in* |
| Percentile-for-Height, *P*(*h*) | 23.18 | 26.76 | 36.69 |
| Estimated-Adult Height (*cm*) | 158.49 | 159.27 | 161.01 |
| Estimated-Adult Height (*ft–in*) | 5 *ft* 2.40 *in* | 5 *ft* 2.71 *in* | 5 *ft* 3.39 *in* |
| Current-Age-MP Height (*cm*) | 131.88 | 134.11 | 138.74 |
| Δ Height *w. r. t.* Current-Age-MP (*cm*) | +4.53 | +5.59 | +7.79 |
| Status (pertaining-to-height), $STATUS_{\pm}(h)$ | +3.43% | +4.17% | +5.61% |
| **Qualitative Status (pertaining-to-height)** | 1st-Degree Tall | 1st-Degree Tall | 1st-Degree Tall |
| Current-Age-Army-Cutoff Height (*cm*) | 135.42 | 137.80 | 142.57 |
| Δ Height *w. r. t.* Army-Cutoff (*cm*) | +0.99 | +1.90 | +3.96 |
| Reference Height (*cm*) | 136.41 | 139.70 | 146.53 |
| Percentile-for-Reference-Height | 23.18 | 26.76 | 36.69 |
| Age of Prediction, *A+* (*years*) | 11.14 | 11.54 | 12.23 |
| Reference Height at *A+* (*cm*) | 139.52 | 143.16 | 150.06 |
| 6-Month-Height Management (*cm*) | 3.11 | 3.46 | 3.53 |
| **Month-Wise-Height Management (*cm/month*)** | **+0.52** | **+0.58** | **+0.59** |
| Month-Wise-Height Management (*in/month*) | +0.20 | +0.23 | +0.23 |
| Gross Mass (*kg*) | 42.50 | 46.50 | 49.60 |
| Clothing Correction (*kg*) | 0 | 0 | 0 |
| Net Mass, $\mu$ (*kg*) | 42.50 | 46.50 | 49.60 |
| Net Weight (*lb-oz*) | 93 *lb* 11.40 *oz* | 102 *lb* 8.52 *oz* | 109 *lb* 5.89 *oz* |
| Percentile-for-Net-Mass $P(\mu)$ | 78.36 | 82.41 | 80.85 |
| Estimated-Adult Mass (*kg*) | 67.98 | 70.54 | 69.56 |
| Estimated-Adult Weight (*lb–oz*) | 149 *lb* 14.41 *oz* | 102 *lb* 8.52 *oz* | 153 *lb* 5.97 *oz* |
| *BMI*: Body-Mass Index ($kg/m^2$) | 22.84 | 23.83 | 23.10 |
| Estimated-Adult *BMI* ($kg/m^2$) | 27.07 | 27.81 | 26.83 |
| Optimal Mass (*kg*) | 30.94 | 33.16 | 37.82 |
| Δ Mass-for-Height (*kg*) | +11.56 | +13.34 | +11.78 |
| Status (pertaining-to-mass), $STATUS_{\pm}(\mu)$ | +37.35% | +40.24% | +31.16% |
| **Qualitative Status (pertaining-to-mass)** | 4th-Degree Obese | 4th-Degree Obese | 4th-Degree Obese |
| Optimal Mass for Reference Height at *A+* (*kg*) | 32.83 | 38.23 | 39.88 |
| 6-Month-Mass Management (*kg*) | –9.67 | –8.27 | –9.72 |
| **Month-Wise-Mass Management (*kg/month*)** | **–1.61** | **–1.38** | **–1.62** |
| Month-Wise-Mass Managment (*lb-oz/month*) | –3 *lb* 8.80 *oz* | –3 *lb* 0.69 *oz* | –3 *lb* 9.15 *oz* |
| Nutritional Status | Over-Nutrition | Over-Nutrition | Over-Nutrition |

dation to gain mass; Table 3*b* shows 'Growth-and-Obesity Roadmap' for an obese child, with month-wise recommendation to lose mass), generalizations of 'Growth-and-Obesity-Moving Profiles', which were introduced through KJR Model, described in the last section, one needed more than one profile — each profile represented a checkup (Kamal *et al.*, 2013*e*; 2014*a*). The maximum value from members (elements) of the following set, as given in (11)

$$\{h, h_{\text{cuurent-age-MP}}, h_{\text{army-cutoff}}\} \quad (11)$$

(first member of this set is the measured height, second one is the current-age-mid-parental height and third one the army-cutoff height) gave the reference height. Optimal mass, after 6 *months*, was computed based on the estimated-reference height (6 *month* ahead in time scale). Recommendations to pick up height and gain or reduce mass (weight) were generated from the most-recent profile. Difference of measured mass (current value) and optimal mass (after 6 *months*) was considered as guideline to set short-term goals to gain (lose) mass within the next 6 *months*, if the value was negative (positive). Month-wise recommendations to gain height or acquire (reduce) mass were prepared, taking care of the principle that a child should not be required to lose more than 10 *kg* within the next 6 *months*, in order to avoid any adverse health effects from a rapid loss of mass.

A more efficient way is to deal with percentiles of height instead of the actual values. One of the advantages of this approach is that during subsequent profile generation, only percentile of current height needs to be computed, as gender-specific-army-cutoff-height percentile remains unchanged for a given country, say Pakistan (for males its value comes out to 2.718014592103645… and for females 19.35609323536863…), and gender-specific-MP-height percentile does not change for a given family. Further, it is the maximum of 3 percentiles that is needed to compute height 6-*month* down the road, not the actual height. To determine percentile of reference height, $P_{\text{ref}}$, select the larger value from the pair of values consisting of percentile of current height, $P(h)$, and maximum of gender-specific-army-cutoff-height percentile, $P_{\text{army-cutoff}}$, as well as gender-specific-MP-height percentile, $P_{\text{MP}}$. Equations (12*a*, *b*) explain this procedure

$$P_{\max} = max(P_{\text{army-cutoff}}, P_{\text{MP}}) \quad (12a)$$

$$P_{\text{ref}} = max(P(h), P_{\max}) \quad (12b)$$

*Worked Examples*: **Additional File 1** (http://www.ngds-ku.org/Papers/J35/Additional_File_1.pdf) contains detailed Growth-and-Obesity Roadmaps of S. and J. Families (parents and all siblings), roadmaps of eldest sibling of each family are included in this paper as Tables 3*a*, *b*.

***Validation***

Children's Growth-and-Obesity Roadmaps were validated by predicting heights and masses on the day of second and subsequent checkups based on values of current and previous checkups. The predicted heights (masses) were compared using the formula**:**

$$\%\ \text{matching} = 100\left(1 - \frac{|\text{Predicted} - \text{Actual}|}{|\text{Actual}|}\right) \quad (13)$$

Results of prediction are reported in **Additional File 2** (http://www.ngds-ku.org/Papers/J35/Additional_File_2.pdf).

***Software Development***

Growth-and-Obesity-Roadmap Software (SOFT-GROWTH) was developed and tested to generate reports for the students of a local school, participating in the study.

*Salient Features***:** The tool used was Microsoft Visual Studio (Visual Basic Dot Net 2008) and reports are saved in both word and excel files.

*a)* Input data could be entered manually or read through word/excel file.
*b)* Data were validated (no undefined or out-of-bound values).
*c)* Age was calculated and interval identified, $A \geq 30$, $20 \leq A < 30$, $A < 20$, ($A$ represented age in *years*).
*d)* If $A \geq 30$, optimal mass was calculated using standard *BMI* (*i. e.*, 24 $kg/m^2$).
*e)* If $20 \leq A < 30$, Obesity Profile was generated by using linear interpolation.
*f)* If $A < 20$, check was performed as to whether parental height was available or not. If the answer was in the affirmative, Growth-and-Obesity Profile was generated. Else, only Obesity Profile was generated. Both of these profiles were generated by using box interpolation, which included quantitative and qualitative statuses.
*g)* Height and mass (weight) were predicted 6 *months* down the road (or any other date) based on reference

height.

*h)* Month-wise recommendations generated to gain height and put on/lose mass (weight) for children.

*i)* Detailed-report preparation in word file as well as excel file.

*Technical Details*: **Additional File 3** (http://www.ngds-ku.org/Papers/J35/Additional_File_3.pdf) gives the algorithm, the flow chart and the screen shots.

***Diet and Exercise Plans***

These month-wise targets could be achieved by a suitable combination of diet, exercise and lifestyle adjustment (Kamal *et al.*, 2014*b*, 2014; Kamal and Khan, 2014). To increase height, the child's diet should be high in calcium and protein as well as fiber. Stunted children should do light-stretching exercises, wearing minimal clothing, in a park after sun has just come out. Such children may, also, be encouraged to exercise during TV-watching. In addition, parents should increase their sleep-duration to 9 hours or more (Kamal *et al.*, 2013*b*). To gain weight, a person's diet should include potato items as well as food with high-protein content. Such individuals should avoid food, which is rich in fiber. Their exercise routine should consist of heavy exercises. These exercises should be done consistently. However, their duration should be short during a typical day. To lose weight, a child should consume salad and yogurt. Obese child's routine for exercise should consist of light exercises, which should be done consistently. However, their duration should be long during a typical day (Kamal *et al.*, 2013*d*). One must realize that all diet-based interventions, for height and weight management, would be ineffective, if the child is suffering from vitamin-D deficiency (Kamal *et al.*, 2013*a*).

## CONCLUSION AND FUTURE DIRECTIONS

Proper weight-for-height is the basis of lifelong physical, mental, emotional as well as social fitness (Kamal and Khan, 2013). In this work the authors have taken up the problem of optimal height and weight management in children. Since a child is growing, a proper recommendation to gain or lose weight cannot be made unless the growth pattern of child is modeled and optimal mass at a future date is determined on the basis of desired height on that date. The key contributions of this research are**:**

- Month-wise recommendations to gain height and put on/lose mass (weight)
- Statuses, pertaining-to-height and -mass, defined as (negative, zero and positive) real numbers, removing absolute values from the formulae, to make these quantities suitable for mathematical/statistical processing
- Qualitative statuses, pertaining-to-height and pertaining-to-mass defined by adding appropriate adjective (1$^{st}$ to 4$^{th}$ degree) to stunted/tall and wasted/obese
- Statuses, pertaining-to-height and pertaining-to-mass, shown in coördinate-system representation — over-nutrition (tallness + obesity) in 1$^{st}$ quadrant; energy-channelization (tallness + wasting) in 2$^{nd}$ quadrant; under-nutrition (stunting + wasting) in 3$^{rd}$ quadrant; energy-channelization (stunting + obesity) in 4$^{th}$ quadrant
- BMI-based definition of optimal mass for individual older than 30 *years*

Future work needs to focus on developing Pakistani Growth Charts based on standardized anthropometric protocols and proper statistical design (Kamal *et al.*, 2013*f*), preferably preparing charts for different somatotypes — ectomorph, mesomorph and endomorph. Some preliminary work in this direction has, already, been initiated (Aziz *et al.*, 2012; Kamal and Jamil, 2014; Mushtaq *et al.*, 2012). Another important development could be extension of this model to generate Growth-and-Obesity Roadmaps of still-growing parents by extending the method presented earlier (Kamal and Jamil, 2012).

The method proposed and the associated software may assist pediatricians, nutritionists, sport coaches and community-health professionals, involved in the health-protection and the well-being of children, to plan efficient and effective intervention strategies so that stunting, wasting and obesity may be prevented in the next generation of Pakistan, if combined with an approach to change community beliefs and attitude as well as create awareness about child obesity (Aslam *et al.*, 2013) based on facts instead of myths and assumptions (Casazza *et al.*, 2013).

## ENDNOTES

[a]The terminologies underweight and overweight replaced by wasted and obese with appropriate adjectives

[b]Estimated-adult height, $h_{\text{est-adult}}$, is the height at the age of 20 years corresponding to percentile of current height, computed using the technique of linear interpolation. Similar definition holds for estimated-adult mass, $\mu_{\text{est-adult}}$.

[c]http://www.ngds-ku.org/ngds_folder/Protocols/NGDS_form.pdf

[d]http://www.ngds-ku.org/SGPP/SGPP_form.pdf

[e]For adults older than 30 years, age-20 values of height and mass read from extended-gender-specific tables (http://www.ngds-ku.org/Papers/J34/Additional_File_3.pdf) may be misleading for the purpose of computing percentiles. The weight distribution changes, significantly, as years are added up to age of an individual. Hence, it is not recommended to evaluate such percentiles, as they are not needed to generate Obesity Profiles.

[f]All dates are given in the format *YYYY-MM-DD* (year-month-day).

[g]Photographs and scanned signatures on the day, check up was conducted. In order to protect the privacy of S. and J. Families, the photographs, inserted in these Growth-and-Obesity Roadmaps, do not show the actual children, although they are from the set of patients, who reported to SF-Growth-and-Imaging Laboratory for checkups.

[h]Ages are given in both formats**:** fractional years and *YY-MM-DD* (year-month-day).

[i]Dress Code is explained in (Kamal, 2006).

[j]Behavior code is explained in (Kamal, 2006; Kamal *et al.*, 2002).

[k]Cumulative-Scoliosis-Risk Weightage (CSRW) is described in (Kamal *et al.*, 2013*c*).

## REFERENCES


Abolfotouh, M. A., H. A. H. Abu-Zeid, I. A. Badawi and A. A. Mahfouz (1993). A method for adjusting the international growth curves for local use in the assessment of nutritional status of Saudi pre-school children. *Journal of Egyptian Public Health*, 68**:** 688-702

Al Frayh, A. S. and E. A. Bamgboye (1993). The growth pattern of Saudi Arabian pre-school children in Riyadh compared to NCHS/CDC reference population. *Journal of Royal Society of Health*, 113**:** 234-239

Apell, S. P., O. Wahlsten and H. Gawlitza (2011, September 1). Body mass index — a physics perspective. *Report Number CPL 145 397*, Cornell University Library, Ithaca, NY, USA, citation**:** arXiv**:**1109.0296 [physics.pop-ph]

Argyle, J., A. H. Seheult and D. Wooff (2007). Correlation models for monitoring child growth. *Statistics in Medicine*, 27**:** 888-904 (published online)

Aslam, S., Y. Iqbal and A. Ghouri (2013). Community beliefs, attitude and awareness about child obesity. *The Shield (International Journal of Physical Education and Sport Science)*, 8**:** 1-25

Ayatollahi, S. M. T. (1993). Weight-for-height of South Iranian school children and the NCHS reference data. *International Journal of Obesity*, 17**:** 471-474

Aziz, S., W. Noor-ul-Ain, R. Majeed, M. A. Khan, I. Qayam, I. Ahmed and K. Hosain (2012). Growth centile charts (anthropometric measurement) of Pakistani pediatric population. *Journal of Pakistan Medical Association*, 62**:** 367-377

Baker, J. L., L. W. Olsen and T. I. A. Sørensen (2007). Childhood body-mass index and risk of coronary heart disease in adulthood. *New England Journal of Medicine*, 357**:** 2329-2337

Barker, D. J. P., C. Osmond, I. Rodin, C. H. D. Fall and P. D. Winter (1995). Low-weight gain in infancy and suicide in adult life. *BMJ*, 311**:** 1203

Barthel, B., C. Cariou, E. Lebas-Saison and I. Momas (2001). Prévalence de l'obésité chez l'enfant**:** etude dans les écoles prmares publiques parisiennnes (Prevalence of obesity in childhood**:** study in Paris elementary schools). *Santé Publique*, 13**:** 7-15

Bibbins-Domingo, K., P. Coxson, M. J. Pletcher, J. Lightwood and L. Goldman (2007). Adolescent overweight and future coronary heart disease. *New England Journal of Medicine*, 357**:** 2371-2379

Casazza, K., K. R. Fontaine, A. Astrup, L. L. Birch, A. W. Brown, M. M. B. Brown, N. Durant, G. Dutton, E. M. Foster, S. B. Heymsfield, K. Mclver, T. Mehta, N. Menachemi, P. K. Newby, R. Pate, B. J. Rolls, B. Sen, D. L. Smith, Jr., D. M. Thomas and D. B. Allison (2013). Myths, presumptions, and facts about obesity. *New England Journal of Medicine*, 368**:** 446-454

Chianese, J. (2005). Short stature. *Pediatrics in Review*, 26**:** 36-37 — includes comment by Adam HM (Editor, In Brief)

Cole, T. J., M. C. Bellizzi, K. M. Flegal and W. H. Dietz (2000). Establishing a standard definition for child overweight and obesity worldwide**:** international survey. *British Medical Journal*, 320**:** 1-6

De Onis, M., A. Onyango, E. Borghi, A. Siyam, M. Blössner, C. Lutter**:** WHO Multicentre Growth Reference Study Group (2012). Worldwide implementation of the WHO Child Growth Standards. *Public Health and Nutrition*, 15**:** 1603-1610

Eknoyan, G. (2008). Adolphe Quetelet (1796-1874) — the average man and indices of obesity. *Nephrology Dialysis Transplantation*, 23**:** 47-51

Fontaine, K. R., D. T. Redden, C. Wang, A. O. Westfall and D. B. Allison (2003). Years of life lost due to obesity. *Journal of the American Medical Association*, 289**:** 187-193

Hermanussen, M. and C. Meigen (2003). Synthetic standards for body weight. *HOMO*, 54**:** 142-156

Kamal, S. A. (2006, May 23). *Manual for Obtaining Anthropometric Measurements*. University of Karachi, Karachi, Pakistan, full text**:** http://www.ngds-ku.org/ngds_folder/M02.pdf

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*b*, 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

Kamal, S. A., C. M. S. Manzoor and S. A. Khan (2013*a*, September 4, 5). Diet-based interventions and vitamin-D deficiency. *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. 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 (ANTHROMATHEMATICS 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., M. Sarwar and U. A. Razzaq (2013*c*, September 4, 5). Cumulative-Scoliosis-Risk Weightage (CSRW) — designing preventive strategies. *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. 11, abstract#Anthro13-05**:** http://www.ngds-ku.org/Presentations/CSRW.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**:** 87-96, full text**:** http://www.ngds-ku.org/Papers/J29.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 Biligirami (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. 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**:** 401-419, full text**:** http://www.ngds-ku.org/Papers/J33.pdf

Kamal, S. A., S. Burki and S. S. Jamil (2013*d*, September 4, 5). Optimal-weight management through diet, exercise and life-style 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., S. Firdous and S. J. Alam (2004). An Investigation of growth profiles of the Pakistani children. *International Journal of Biology and Biotechnology*, 1**:** 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**:** Software to analyze growth of a child (a telemedicine perspective). *National Telemedicine Conference Pakistan 2002*, Technology Resource Mobilization 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**:** 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 Journal of Biology and Biotechnology*, 11**:** 623-648, full text**:** http://www.ngds-ku.org/Papers/J34.pdf

Kamal, S. A., S. S. Jamil and S. A. Ansari (2013*e*, 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**:** 147-153, full text**:** http://www.ngds-ku.org/Papers/J32.pdf

Kamal, S. A. and U. A. Razzaq (2014, March 20). Accuracy, precision and reproducibility in measurements of masses (weights). *The Second Conference on Mathematical Sciences (CMS 2014)*, Department of Mathematics, University of Karachi, Karachi, Pakistan, p. 2, abstract#CMS14-03**:** http://www.ngds-ku.org/Presentations/Accuracy.pdf

Kamal, S. A., U. A. Razzaq and S. S. Jamil (2013*f*, September 4, 5). Importance of standardization of anthropometric protocols. *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

Karlberg, J. (1996). Computer simulation of final height after growth-promoting therapy. *Acta Pediatrica Supplement*, 417**:** 61-3

Karlberg, J., Y. B. Cheung and Z. C. Luo (1999). An update on the update of growth charts. *Acta Pediatrica*, 88**:** 797-802

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

Lee, H., K. M. Harris and J. Lee (2013). Multiple levels of social disadvantage and links to obesity in adolescence and young adulthood. *Journal of School Health*, 83**:** 139-149

Ludwig, D. S. (2007). Childhood obesity — the shape of things to come. *New England Journal of Medicine*, 357**:** 2325-2327

Mozaffarain, D., T. Hao, E. B. Rimm, W. C. Willett and F. B. Hu (2011). Changes in diet and lifestyle and long-term weight gain in women and men. *New England Journal of Medicine*, 364**:** 2392-2404

Mushtaq, M. U., S. Gull, K. Mushtaq, H. M. Abdullah, U. Khurshid, U. Shahid, M. A. Shad and J. Akram (2012). Height, weight, *BMI* percentiles and nutritional status relative to the international growth reference among Pakistani school-aged children. *BMC Pediatrics*, 12**:** 31-42

Ramzan, M., I. Ali, A. S. Khan (2008). Body-mass status of school children of Dera Ismail Khan, Pakistan. *Journal of Ayub Medical College*, 20**:** 119-121

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**:** 755-762

WHO Multicentre Growth Reference Study Group (2006*a*). Reliability of anthropometric measurements in the WHO Multicentre Growth Reference Study. *Acta Paediatrica Supplement*, 450**:** 38-46

WHO Multicentre Growth Reference Study Group (2006*b*). WHO child growth standards based on length/height, weight and age. *Acta Paediatrica Supplement*, 450**:** 76-85

Wilkand, K. A., Z. C. Luo, A. Niklasson and J. Karlberg (2002). Swedish population-based longitudinal reference values from birth to 18 years of age for height, weight and head circumference. *Acta Paediatrica*, 91**:** 739-754

Yanovski, S. Z. and J. A. Yanovski (2011). Obesity prevalence in the United States — up, down, or sideways? *New England Journal of Medicine*, 364**:** 987-989 (perspective)

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