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KJ-REGRESSION MODEL TO EVALUATE OPTIMAL MASSES OF EXTREME CASES[¶]

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ABSTRACT

Optimal mass (weight) was defined in 2011 as the mass (weight) corresponding to percentile of height. Status of obesity was determined as percentage, by considering optimal mass as reference and could be used in conjunction with body-mass index (*BMI*) to classify an individual as obese or wasted. This work puts forward a regression model (named as KJ-Regression Model) to evaluate optimal masses of children and adults, whose heights and masses lie below third percentile or above ninety-seventh percentile. For such cases, CDC growth charts, converted into tabular form, cannot be used to determine numerical values of percentiles. Sigmoid function and linear interpolation were used to compute heights and masses corresponding to extreme percentiles (below 3rd or above 97th). In addition to growth curves (plots of height and mass versus age), which include plots corresponding to 0.01th, 0.1th, 1st, 99th, 99.9th and 99.99th percentiles, mathematical formulae are given to compute heights and masses corresponding to any value of percentile (between zero and hundred). Height and mass tables for boys and girls with entries to 5 decimal places, including those corresponding to extreme percentiles, are given in additional files.

Keywords: Optimal mass, obesity, wasting, stunting, tallness, body-mass index, CDC growth charts

LIST OF ABBREVIATIONS

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

BIA: **B**ioelectrical-**I**mpedance **A**nalysis
BMI: **B**ody-**M**ass **I**ndex
DEXA: **D**ual-**E**nergy-**X**-ray **A**bsorptiometry
DXA: **D**ual-**E**nergy-**X**-ray **A**bsorptiometry
NGDS: **N**ational **G**rowth and **D**evelopmental **S**tandards for the Pakistani Children
SF: **S**yed **F**irdous
SGPP: **S**ibling **G**rowth **P**ilot **P**roject — a subproject of the NGDS Pilot Project

INTRODUCTION

Systematic study of anthropometric measurements is found as early as the eighteenth century, when height was considered to be a marker of physical development and an indicator of economic growth. The mid 1970s found expanded use of anthropometrics in social sciences and anthropometric quantities started to be employed as indicators of quality of life, *e. g.*, design of furniture, computer keyboards and exercise equipment.

One of the areas, which is of prime concern to modern man is maintenance of optimal weight-for-height, which is supposed to lead the incumbent to a healthier life in the old age (Mozaffarain *et al.*, 2011) and create a better body image in younger population (Lee *et al.*, 2013). Years of life may be decreased, if obesity is exhibited during childhood and adolescence (Fontaine *et al.*, 2003). Wasting, in contrast, is correlated with depression at the individual level and suicidal rates at the population level (Barker *et al.*, 1995). Communities worldwide measure heights and weights of children to determine prevalence of obesity (Albertson-Wilkand *et al.*, 2002; Barthel *et al.*, 2001). There is a need to study perceptions of elementary school personnel on childhood obesity (Odum *et al.*, 2013) to make policies for bringing about change in community beliefs and attitudes by creating awareness about the problem (Aslam *et al.*, 2013; Casazza *et al.*, 2013). During the last 5 *years*, the issue of childhood obesity has been highlighted (Ludwig, 2007), because the American government has taken the problem as national priority (Yanoviski and Yanoviski, 2011) and school-based obesity prevention programs have been put in practice (Tuckson, 2013; Moreno *et al.*, 2013; Pbert *et al.*, 2013). 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*b*). Another problem arises when heights and weights lie outside the range covered by the existing growth charts.

[¶]The italic superscripts [*a*], [*b*], [*c*], …, appearing in the text, represent endnotes listed before references.

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This work describes a regression model (referred by the name 'KJ-Regression Model') to compute optimal masses of children and adults, whose height and mass percentiles lie outside the interval ($3 \leq P \leq 97$). Such cases present a real challenge as CDC Growth Tables cannot be employed to give numerical values of extreme percentiles. The job was done by using sigmoid function and linear interpolation. Plots and tables of heights and masses for various ages, including those representing 0.01th, 0.1th, 1st, 99th, 99.9th and 99.99th percentiles as well as mathematical formulae are made available to compute heights and masses corresponding to any value of percentile, P ($0 \leq P < 100$) and vice versa. There was a long-felt need of updating of growth charts (Karlberg *et al.*, 1999). A humble attempt is made in this paper.

METHODS AVAILABLE FOR ASSESSMENT OF OBESITY

Many methods are used for assessment of growth and obesity. The review presented below is categorized into 3 categories**:** *a*) non-anthropometric measures of obesity, *b*) anthropometric measures of obesity and *c*) assessment of height status (*cf.* Figure 1)

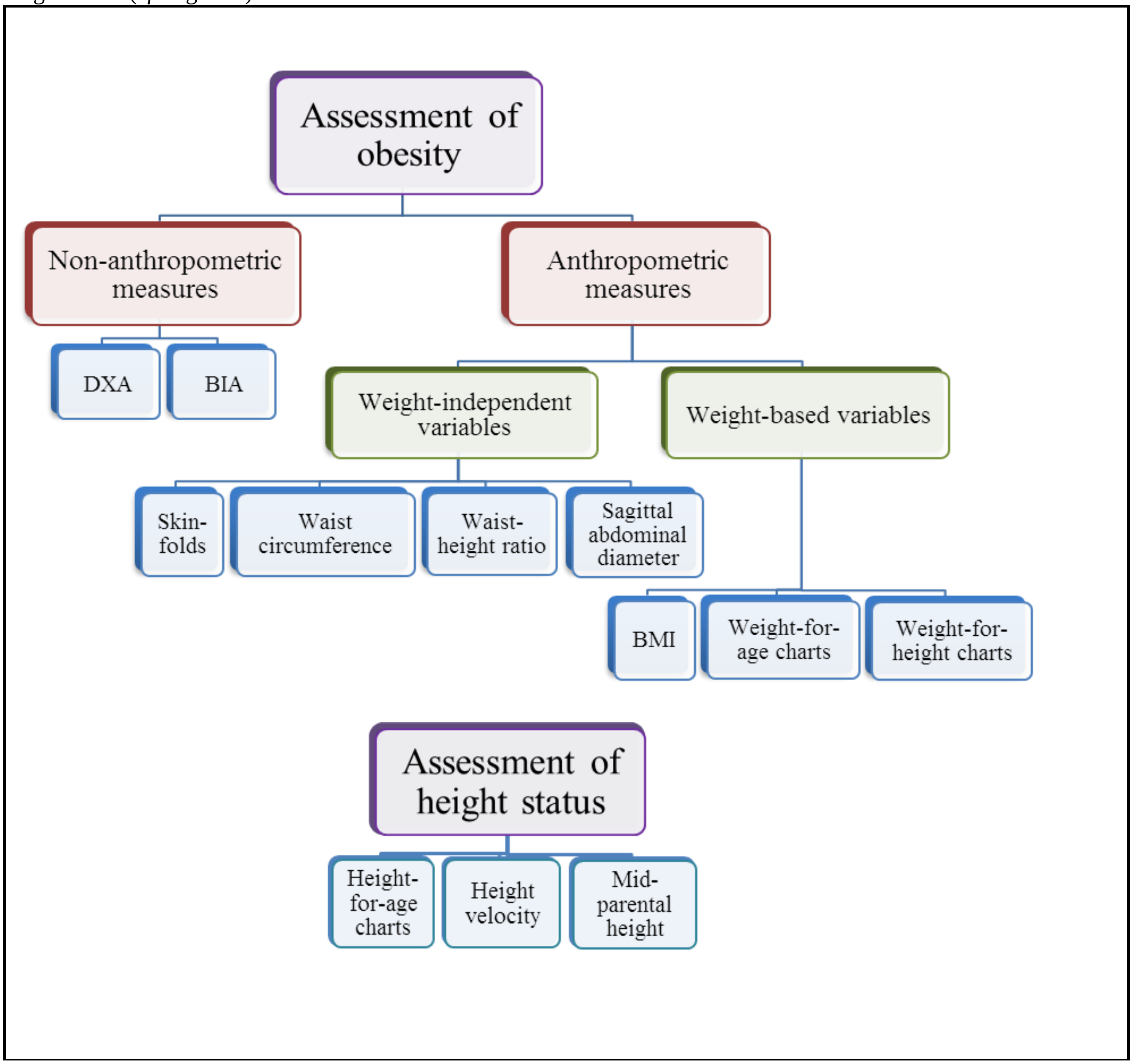


Fig. 1. Classification of methods available for the assessment of obesity and height status (http://www.ngds-ku.org/Papers/J34/Fig_1.htm)

Non-Anthropometric Measures of Obesity

DXA or DEXA (Dual-Energy-X-ray Absorptiometry) gives precise measures of muscle mass, bone mass and adiposity (Shah and Braverman, 2012). The principle underlying this technique is that the amount of photon energy absorbed by bone depends upon bone-mineral content, making it the standard measurement of adiposity level, universally. Bioelectrical-Impedance Analysis (BIA) works upon the assumption that fat-free mass, due to its higher water content, has a high electrical conductivity as compared to fat mass. Equations have been derived to estimate percentage-body fat (BF%) from measurements of electrical impedance through the human body. These estimates have shown a good correlation with DXA (Pallan, 2011).

DXA scanners have a high cost. Further, being full-body scanners, employing two low-dose X-ray radiators, they impose serious health risks to human body, in particular, eyes and gonads and are not recommended for pregnant women, children, cancer survivors and those having infections (Kamal, 2010*b*). In extremely obese individuals, DXA might not be able to give accurate results. On the other hand, BIA equipment is even more expensive and weighty, making its difficult to implement this technique in field studies. This is the reason that it is considered as inappropriate for epidemiological studies, clinical studies and routine examinations (Boeke *et al.*, 2013; Stettler *et al.*, 2007).

Anthropometric Measures of Obesity

A wide range of anthropometric indices is being utilized as obesity measures. Anthropometric techniques, being inexpensive and non-invasive for obesity determination, are classified into two groups — indices based on weight and indices not based on weight**:**

*Weight-Independent-Anthropometric Variables***:** These variables include, skin-folds (biceps, triceps, supra-iliac and sub-scapular), sum of skin-folds, waist circumference, hip-circumference, ratio of waist-circumference to hip-circumference, ratio of waist-circumference to height, sagittal-abdominal diameter, *etc.* and are considered direct measures of obesity — not involving mass (weight) measurement. Formulae to estimate percentage-body fat (BF%) of subjects are available. These measurements require a lot of training of anthropometrists and do not have intra-observer and inter-observer reproducibility and repeatability. Therefore, these techniques do not have the required sensitivity and specificity in identifying people as obese and non-obese. Moreover, there is a lack of references, standards and cut-off points of these variables at local and international levels.

*Weight-Based-Anthropometric Variables***:** Mass **(**Weight) and height, are simple-to-produce, easy-to-measure, reproducible and reliable measures, provided standardized protocols are followed (Kamal, 2006; Kamal *et al.*, 2013*d*; Kamal and Razzaq, 2014). The indices and the methods for assessing status of obesity that are based on measurements of, either or both mass (weight) and height, are more reliable and not prone to so many errors. Top of the list of such indices, is body-mass index (*BMI*), explained in detail later in this paper. Other, routinely used, methods include weight-for-age, and weight-for-height growth charts. *BMI* and growth charts are, universally, used in defining overweight, obesity and thinness in statistical studies as well as for determining health status of patients.

Assessment of Height Status

Height is considered to represent a child's nutritional (Rovner and Zemel, 2013) as well as medical history. The nutritional conditions faced by a child during the course of life are depicted in height trajectory, in particular, chronic diseases and persistent infections, which are thought to, significantly, affect a child's longitudinal growth, whereas sociological factors contribute, weakly, towards height gain. Below are listed the most common methods employed for assessing the status of children's height**:**

*Height-for-Age Charts***:** Pediatricians, all over the world, use definitions of stunting and tallness to monitor growth patterns of children. The drawbacks of these charts are that they do not, directly, account for hereditary effects and are representative of population-specific environmental factors.

*Height Velocity***:** To determine 'height velocity' (at times called 'growth velocity') one needs at least two (or a series of) measurements taken during a period of 6 *months* or so. This variable can indicate current growth faltering. Drawback is that half-a-year period of evaluation is required to determine height velocity, which is not advisable for critically ill children. KJK model tried to address this problem (Kamal *et al.*, 2011*b*).

Mid-Parental Height: A number of methods are available to assess children's height, noticeable among them are two formulae. The first one employs arithmetic mean of height of parents (Galton, 1886; Cole, 2000; Garza *et al.*, 2013). The other formula for mid-parental height, also known as 'target height' is computed by adding to (subtracting from) arithmetic mean of parents' heights, 6.5 *cm* for a male (female) child (Tanner *et al.*, 1970) — see the following section. A variation of 5 *cm* from target height on either side is considered normal, although a value of the lower side indicates constitutional delay. A larger deviation may call for closer scrutiny of history of diseases, in particular, infectious diseases, endocrine disorders, kidney malfunction, heart problems or disorders of gastrointes-

Table 1. Adult-mid-parental (target) heights (SGPP-KHI-20100421-03/02) illustrating stunting.

Father's Height**:** 166.80 *cm* • Mother's Height**:** 171.00 *cm*

BOY/GIRL=(FATHER+MOTHER ± 13)/2	*Boy*	*Girl*
Adult-MP (Target) Height (*cm*)	175.40	162.40
Adult-MP Height (*ft-in*)	5 *ft* 9.06 *in*	5 *ft* 3.94 *in*
Percentile of Adult-MP (Target) Height	**43.04**	**44.64**

tract. This variable correlates parents' heights with their offspring in the best possible way. However, there are indications that mid-parental height does not predict very well adult heights of children of shorter parents (Garza *et al.*, 2013).

MID-PARENTAL HEIGHT, STUNTING AND TALLNESS

In the literature, stunting is defined as height falling below 50^{th} percentile. Child is classified as severely stunted, if the individual's height lies below 3^{rd} percentile. Our group defined stunting (*cf*. Tables 1^{a} and 2^{a}) and tall-

Table 2. Growth-and-Obesity Profile of A. E. (SGPP-KHI-20100421-03/02) illustrating stunting.

Gender**:** Male • Date of Birth**:** 2005-02-19

Checkup	*1st*
Date of Checkup	2011-05-22
Age (*years*)	6.25
Dress Code[§]	0/0.5
Height (*cm*)	106.20
Height (*ft-in*)	3 *ft* 5.81 *in*
Percentile-for-Height	**2.35**
Estimated-Adult Height (*cm*)	161.69
Estimated-Adult Height (*ft-in*)	5 *ft* 3.66 *in*
Mid-Parental-Height Percentile	43.04
Current-Age-MP Height (*cm*)	116.05
Δ Height-for-Age (*cm*)	–9.85
Δ Height-for-Age (*in*)	–3.88
Status (pertaining-to-height)	**8.48% STUNTED**
Gross Mass (*kg*)	16.30
Clothing Correction (*kg*)	0
Net Mass (*kg*)	16.30
Net Weight (*lb-oz*)	35 *lb* 15.06 *oz*
Percentile-for-Net-Mass	2.39
Estimated-Adult Mass (*kg*)	51.97
Estimated-Adult Weight (*lb–oz*)	114 *lb* 9.38 *oz*
BMI**:** Body-Mass Index (kg/m^2)	14.45
Estimated-Adult BMI (kg/m^2)	19.88
Optimal Mass (*kg*)	16.26
Optimal Weight (*lb-oz*)	35 *lb* 13.72 *oz*
Δ Mass-for-Height (*kg*)	+0.04
Δ Weight-for-Height (*lb–oz*)	+1.34 *oz*
Status (pertaining-to-mass)	0.23 (+)[#]

[§]Dress code explained in (Kamal *et al.*, 2002; Kamal, 2006)

[#](∓) in Status (pertaining-to-mass) means that child under study has lesser (greater) mass as compared to optimal mass, but is not considered wasted (obese) — the child's mass lies within 1% tolerance limit.

Table 3. Adult-mid-parental (target) heights (SGPP-KHI-20080910-01/02) illustrating tallness.

Father's Height**:** 168.90 *cm* • Mother's Height**:** 157.80 *cm*

BOY/GIRL=(FATHER+MOTHER ± 13)/2	*Boy*	*Girl*
Adult-MP (Target) Height (*cm*)	169.85	156.85
Adult-MP Height (*ft-in*)	5 *ft* 6.87 *in*	5 *ft* 1.75 *in*
Percentile of Adult-MP (Target) Height	**16.69**	**16.96**

ness (*cf*. Tables 3[a] and 4[a]) by taking mid-parental height as reference. Adult-mid-parental (target) height of a boy, $h_{\text{MP}-\text{BOY}}$, or a girl, $h_{\text{MP}-\text{GIRL}}$, was computed from biological father's height as *F cm* or 5 *ft x in* and biological mother's height as *M cm* or 5 *ft y in* using the following expressions (Chianese, 2005; Karlberg, 1996; Tanner *et al.*, 1970)**:**

(1*a*) $$h_{\text{MP}-\text{BOY}} = \frac{F+M}{2} + 6.5\ cm = 5\ ft\ (\frac{x+y}{2} + 2.56)\ in$$

(1*b*) $$h_{\text{MP}-\text{GIRL}} = \frac{F+M}{2} - 6.5\, cm = 5\ ft\ (\frac{x+y}{2} - 2.56)\ in$$

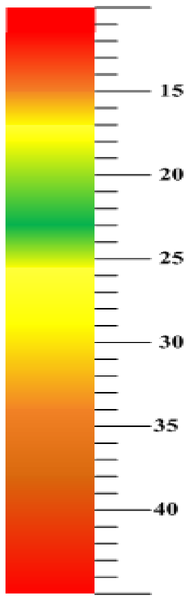
Mid-parental heights have variation of 5 *cm* (1.97 *in*) on either side. Child was considered to be stunted, when the incumbent's height percentile, *P*(*h*), was lesser than percentile of mid-parental height, $P(h_{\text{MP}})$**:**

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

Table 4. Growth-and-Obesity Profile of R. Z. A. (SGPP-KHI-20080910-01/02) illustrating tallness.

Gender**:** Female • Date of Birth**:** 2006-05-30

Checkup	*1st*
Date of Checkup	2009-10-11
Age (*years*)	3.37
Dress Code	0/0.5
Height (*cm*)	102.80
Height (*ft-in*)	3 *ft* 4.47 *in*
Percentile-for-Height	**93.33**
Estimated-Adult Height (*cm*)	173.17
Estimated-Adult Height (*ft-in*)	5 *ft* 8.18 *in*
Mid-Parental-Height Percentile	16.96
Current-Age-MP Height (*cm*)	92.41
Δ Height-for-Age (*cm*)	+10.39
Δ Height-for-Age (*in*)	+4.09
Status (pertaining-to-height)	**11.4% TALL**
Gross Mass (*kg*)	15.50
Clothing Correction (*kg*)	0
Net Mass (*kg*)	15.50
Net Weight (*lb-oz*)	34 *lb* 2.84 *oz*
Percentile-for-Net-Mass	67.80
Estimated-Adult Mass (*kg*)	63.65
Estimated-Adult Weight (*lb–oz*)	140 *lb* 5.72 *oz*
BMI**:** Body-Mass Index (kg/m^2)	14.67
Estimated-Adult BMI (kg/m^2)	21.23
Optimal Mass (*kg*)	17.98
Optimal Weight (*lb-oz*)	39 *lb* 10.46 *oz*
Δ Mass-for-Height (*kg*)	–2.48
Δ Weight-for-Height (*lb–oz*)	–5 *lb* 7.62 *oz*
Status (pertaining-to-mass)	13.81% WASTED



Excessively Wasted	*BMI* < 15
Severely Wasted	15 ≤ *BMI* < 16
Wasted	16 ≤ *BMI* < 18.5
Normal	18.5 ≤ *BMI* < 25
Obese	25 ≤ *BMI* < 30
Moderately Obese	30 ≤ *BMI* < 35
Severely Obese	35 ≤ *BMI* < 40
Excessively Obese	*BMI* ≥ 40

Fig. 2. World Health Organization classification and color-coding for Body-Mass Index (*BMI*) expressed in kg/m^2 — the terminologies underweight and overweight replaced by wasted and obese with appropriate adjectives (http://www.ngds-ku.org/Papers/J34/Fig_2.htm)

whereas the reverse was true for a tall child**:**

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

Our group gave quantitative estimates of tallness and stunting in terms of percentages, taking current-age-mid-parental height as reference (Kamal *et al.*, 2011*b*)

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

1% variation from current-age-mid-parental height (end points included) was considered normal. Tables 1-4[a] contain numerical examples of computation of mid-parental (target) heights for boy and girl, statuses pertaining to height, for tall and stunted children.

BODY-MASS INDEX (BMI)

BMI is short form of *Body-Mass Index*. This index is, basically, used to determine status of wasting or obesity (*cf*. Figure 2). *BMI* of a person is computed by dividing net mass (mass with zero clothing on), μ, of an individual (in *kg*) by square of height of that person, *h* (in *m*) — *kg* stands for 'kilograms' and *m* for 'meters'.

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

BMI is reported in kg/m^2. During 1960s, while exploring various indices dealing with mass (weight) and height, it was observed that in adults, normal body mass (*kg*) was proportional to the square of height (*m*), as proposed by Adolphe Quetelet (1796-1874), Belgian mathematician, astronomer and statistician, in 1832, recognized in the then small circle of experts as the 'Quetelet Index'. In 1972, Ancel Keys (1904-2004) renamed it as 'Body-Mass Index' (Keys *et al.*, 1972). By that time, many ratios of height and mass were suggested, *e. g.* Ponderal Index, which is mass (*kg*) divided by cube of height (*m*). Keys made a comparative study of different indices of obesity and declared *BMI* to be the best predictor of average body-fat percentage.

Table 5. Growth-and-Obesity Profile of G. Z. (NGDS-BLA-2010-4721/F) illustrating wasting.

Gender**:** Female • Date of Birth**:** 2005-10-24

Checkup	*1st*	*2nd*	*3rd*
Date of Checkup	2011-04-21	2012-04-11	2013-05-16
Age (*years*)	5.49	6.46	7.56
Dress Code	0/0.5	0/0.5	0/0.5
Cumulative-Scoliosis-Risk Weightage[@]	2.50	7.00	13.50
Height (*cm*)	113.60	118.68	125.34
Height (*ft-in*)	3 *ft* 8.72 *in*	3 *ft* 10.72 *in*	4 *ft* 1.35 *in*
Percentile-for-Height	**68.18**	**55.16**	**52.24**
Estimated-Adult Height (*cm*)	166.51	164.24	163.73
Estimated-Adult Height (*ft–in*)	5 *ft* 5.55 *in*	5 *ft* 4.66 *in*	5 *ft* 4.46 *in*
Gross Mass (*kg*)	17.30	19.31	21.76
Clothing Correction (*kg*)	0	0	0
Net Mass (*kg*)	17.30	19.31	21.76
Net Weight (*lb-oz*)	38 *lb* 2.34 *oz*	42 *lb* 9.26 *oz*	47 *lb* 15.69 *oz*
Percentile-for-Net-Mass	**24.18**	**24.09**	**23.90**
Estimated-Adult Mass (*kg*)	52.25	52.23	52.18
Estimated-Adult Weight (*lb–oz*)	115 *lb* 3.53 *oz*	115 *lb* 2.71 *oz*	115 *lb* 0.89 *oz*
BMI: Body-Mass Index (*kg*/*m*^{2})	**13.41**	**13.71**	**13.85**
Estimated-Adult BMI (*kg*/*m*^{2})	**18.85**	**19.36**	**19.46**
Optimal Mass (*kg*)	**20.57**	**21.90**	**24.59**
Optimal Weight (*lb-oz*)	45 *lb* 5.63 *oz*	48 *lb* 4.49 *oz*	54 *lb* 3.61 *oz*
Δ Mass-for-Height (*kg*)	–3.27	–2.59	–2.83
Δ Weight-for-Height (*lb–oz*)	–7 *lb* 3.29 *oz*	–5 *lb* 11.24 *oz*	–6 *lb* 3.92 *oz*
Status (pertaining-to-mass)	**15.89% WASTED**	**11.81% WASTED**	**11.52% WASTED**

[@]Cumulative-Scoliosis-Risk Weightage (CSRW) is explained in (Kamal *et al.*, 2013*a*).

Calling *BMI* as ratio of mass to square of height is not appropriate, as ratio is dimensionless, obtained between quantities of same dimension. We can define '*BMI* ratio' as *BMI* divided by unit *BMI* (1 *kg*/*m*^{2}). A much better word is 'index' to refer to *BMI* (Eknoyan, 2008). Some of the weak points of *BMI* are that it fails to consider factors like body-frame size and muscularity, been based on wrong assumptions about fat- and lean-mass distribution in the body. As the person becomes older, height is decreased because of curvature of bones, which results in *BMI* increase, in spite of the fact that mass remains unchanged. *BMI*, also, is unable create a universal threshold for conditions of overweight and underweight, due to inter- and intra-region variations in body compositions. This variation appears when there are different ethnic groups present within the same region. The performance of *BMI* was assessed 4 *years* ago by Okorodudu *et al.* (2010). According to their analysis *BMI* has a high specificity but a low sensitivity to identify adiposity (Shah and Braverman, 2012). Zheng *et al.* (2011) studied relationship of *BMI* with death risk in a large Asian population.

For children, *BMI* range, used for estimating statuses for adults, cannot be used — *BMI* tables are needed for interpretation (Kamal *et al.*, 2013*b*). Karlberg *et al.* (2001) gave *BMI* reference values (mean and standard deviation) for Swedish children. Ramzan *et al.* (2008) studied *BMI* of children of Dera Ismail Khan (a city located in KP Province of Pakistan). Guo *et al.* (1994; 1999; 2002) have discussed predictive value of childhood *BMI* to indicate overweight and obesity in adulthood. Williams (2001) included parents' *BMI* along with *BMI* in childhood and adolescence to study association with overweight at the age of 21 *years.* It is suggested to include pubertal stage along with age, when dealing with *BMI* in pubertal children (Bini *et al.*, 2000). Farloni *et al.* (1988) have investigated usefulness of fasting serum leptin levels in the analysis of *BMI*-cut-off values. *BMI*, however, does not seem to be ideal index as indicator of obesity or wasting, since the underlying relationship between *BMI* cut-off points and their clinical implications as well as health risks are not studied well.

Table 5[a] shows computed values of *BMI* (3 checkups) for a wasted child (percentile of mass lesser than percentile of height).

Table 6. Growth-and-Obesity Profile of Z. J. (NGDS-BLA-2010-4443/H) illustrating obesity.

Gender: Male • Date of Birth: 2005-06-12

Checkup	*1st*	*2nd*	*3rd*
Date of Checkup	2011-04-25	2012-04-19	2013-11-21
Age (*years*)	5.87	6.85	8.44
Dress Code	0/0.5	0/0.5	0/0.5
Cumulative-Scoliosis-Risk Weightage	1.50	7.00	11.00
Height (*cm*)	117.00	123.76	133.12
Height (*ft-in*)	3 *ft* 10.06 *in*	4 *ft* 0.72 *in*	4 *ft* 4.41 *in*
Percentile-for-Height	**68.33**	**70.15**	**66.58**
Estimated-Adult Height (*cm*)	180.26	180.61	179.93
Estimated-Adult Height (*ft–in*)	5 *ft* 10.97 *in*	5 *ft* 11.11 *in*	5 *ft* 10.84 *in*
Gross Mass (*kg*)	24.20	26.81	35.39
Clothing Correction (*kg*)	0	0	0
Net Mass (*kg*)	24.20	26.81	35.39
Net Weight (*lb-oz*)	53 *lb* 5.78 *oz*	59 *lb* 1.86 *oz*	78 *lb* 0.56 *oz*
Percentile-for-Net-Mass	**86.25**	**83.36**	**91.95**
Estimated-Adult Mass (*kg*)	86.40	84.54	91.50
Estimated-Adult Weight (*lb–oz*)	190 *lb* 8.12 *oz*	186 *lb* 6.68 *oz*	201 *lb* 12.25 *oz*
BMI: Body-Mass Index (kg/m^2)	**17.68**	**17.50**	**19.97**
Estimated-Adult BMI (kg/m^2)	**26.59**	**25.92**	**28.26**
Optimal Mass (*kg*)	**21.91**	**24.73**	**29.10**
Optimal Weight (*lb-oz*)	48 *lb* 5.05 *oz*	54 *lb* 8.61 *oz*	64 *lb* 2.47 *oz*
Δ Mass-for-Height (*kg*)	+2.29	+2.08	+6.29
Δ Weight-for-Height (*lb–oz*)	+5 *lb* 0.73 *oz*	+4 *lb* 9.24 *oz*	+13 *lb* 14.08 *oz*
Status (pertaining-to-mass)	**10.44% OBESE**	**8.39% OBESE**	**21.64% OBESE**

Table 6[a] shows computed values (3 checkups) of *BMI* for an obese child (percentile of mass greater than percentile of height).

THE NGDS PILOT PROJECT

The NGDS Pilot Project[b] was initiated after 'Institutional Review Process' taking into account of prevailing ethical and human-right standards (Kamal *et al.*, 2002), employing 'opt-in policy' through 'Informed Consent Form'[c]. SGPP[d] is a subproject of the NGDS Pilot Project, in which families came to SF-Growth-and-Imaging Laboratory for detailed checkup after filling out 'SGPP Participation Form'[e]. Reproducible anthropometrists measured heights, *h*, and masses of families to accuracies of 0.01 *cm* and 0.01 *kg*, in the morning hours, according to protocols developed by the NGDS Team (Kamal, 2006; 2010*a*). Parents were in minimal indoor clothing and the children completely undressed except short underpants, everything else removed, including accessories (*cf.* Figure 3). Everyone removed shoes and socks for measurements. Prior to each measurement session, equipments were calibrated and zero errors determined. 'Gross masses' (masses in indoor clothing) were con-

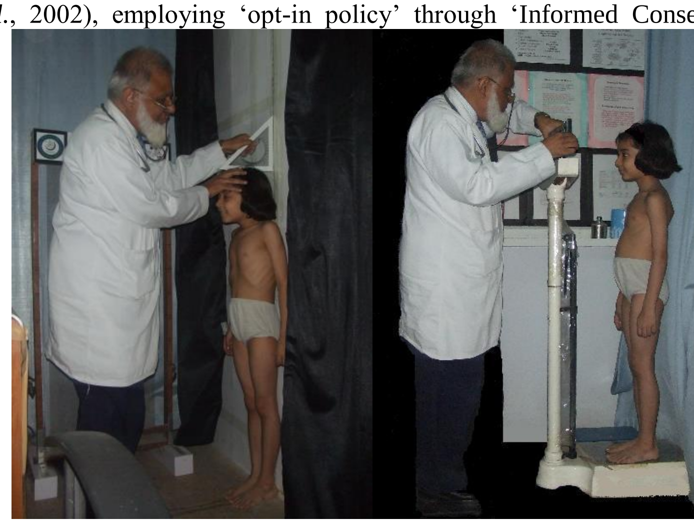


Fig. 3. Height and mass of a girl measured in SF-Growth-and-Imaging Laboratory (http://www.ngds-ku.org/Papers/J34/Fig_3.htm)

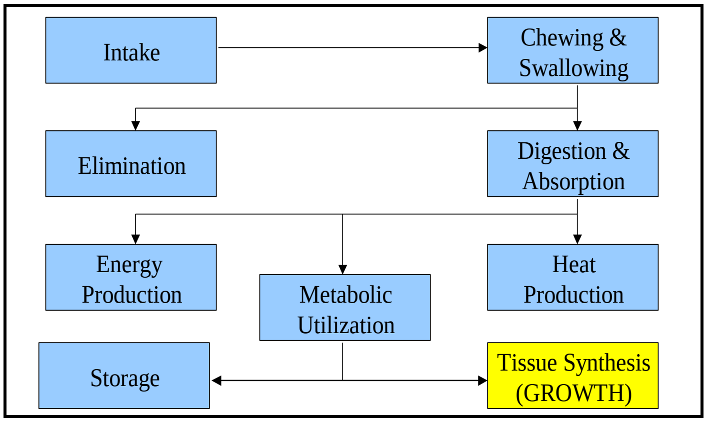


Fig. 4. Mechanism of growth**:** The journey of a chunk of bite (http://www.ngds-ku.org/Papers/J34/Fig_4.htm)

verted to 'net masses' (masses with zero clothing on), μ, by subtracting a suitable clothing correction for parents. For the checkups, the children had to fully disrobe, except briefs or panties. Hence, their recorded masses were very close to net masses and used without any clothing correction.

GROWTH MODELS DEVELOPED BY KARACHI UNIVERSITY ANTHROMATHEMATICS GROUP

KFA Model

KFA (Kamal-Firdous-Alam) Model was based on the assumption that the growth curves (height and weight graphs) were linear if the measurements were performed 6-*month* apart (Kamal *et al.*, 2002; 2004) — good approximation for a major portion of ICP curve, except certain regions. These regions were characterized by a rapid change of growth rate, for example, from infancy to childhood phase and childhood to puberty phase. During these phase transitions, the growth curve (height) was continuous, but not smooth (Karlberg, 1987), resulting in height velocity being un-defined during phase transitions. This may be attributed to the redistribution of nutrients between storage and tissue-synthesis channels (*cf.* Figure 4). A comprehensive theory was presented by the authors, which was incorporated in KJR Model (see below). Other than these regions of abrupt transition, height at some age grid (8.0, 8.5 *year*, *etc.*) was computed using linear interpolation. Adult-mid-parental (target) heights for boys and girls were computed using the expressions (1*a*, *b*).

There was a backward extrapolation of these computed heights to evaluate desired heights at the reference age grids. These heights were compared with the interpolated-actual heights at the same age to determine whether the child was 'stunted' (lesser height-for-age) or 'tall' (excess height-for-age). Similar calculations were done for mass (weight) to determine if the child was 'wasted' (lesser mass-for-height) or 'obese' (excess mass-for-height). *BMI* was compared with the reference value to determine obesity profile. In addition, optimal mass for a given height was determined and compared with the actual mass to find out whether the child was 'wasted' (lesser mass-for-height) or 'obese' (excess mass-for-height). The model had provisions to compute height velocities and rates of gain/loss of weight, in order to predict height and mass (weight) during the next 6 *months*.

KJR Model

A mathematical-statistical model was developed to study the case of J. Family, termed as KJR (Kamal-Jamil-Razzaq) Model (Kamal *et al.*, 2014*b*), which is an extension of KFA Model (Kamal *et al.*, 2004) Boy's or girl's target height (in *cm*) was evaluated by adding or subtracting 6.5 *cm* to or from average height of biological parents. Since Pakistani growth charts were not available at the time of examinations, target height was considered to be the best estimate of family-growth patterns. For adults, *BMI* was compared with the reference value (for the region) to determine, roughly, if an adult was wasted or obese. For children, *BMI* interpretation was different from adults since there was a lack of fixed range, which could be used to label children possessing excess (lesser) mass-for-height. *BMI* tables are available for the younger population, which interpret this index in terms of percentiles read off from tables.

For the purpose of computing 'Growth-and-Obesity-Moving Profiles', presented here, this model was, slightly, modified. The word 'moving profile' was taken from the statistical terminology 'moving average', and propagates the extended concept of profile from the 'snap shot' health status to a 'time series', giving the 6-*month* average. The physicians, these days, are more interested in these types of indicators, for example, blood glucose of a patient, fasting

Table 7. Growth-and-Obesity Profiles of Z. Z. (NGDS-BLA-2011-4784//A) exhibiting pseudo-gains of height and mass

Gender**:** Female • Date of Birth**:** 2006-02-05

Checkup	*1st*	*2nd*	*3rd*
Date of Checkup	2011-05-04	2012-05-03	2013-06-02
Age (*years*)	5.24	6.24	7.32
Dress Code	0/0.5	0/0.5	0/0.5
Cumulative-Scoliosis-Risk Weightage	0.50	4.00	8.50
Height (*cm*)	104.40	109.62	116.33
Height (*ft-in*)	3 *ft* 5.10 *in*	3 *ft* 7.16 *in*	3 *ft* 9.80 *in*
Percentile-for-Height	**15.71**	**9.25**	**9.43**
Estimated-Adult Height (cm)	156.52	154.67	154.75
Estimated-Adult Height (*ft–in*)	5 *ft* 1.62 *in*	5 *ft* 0.89 *in*	5 *ft* 0.92 *in*
Gross Mass (*kg*)	15.30	16.33	17.09
Clothing Correction (*kg*)	0	0	0
Net Mass (*kg*)	15.30	16.33	17.09
Net Weight (*lb-oz*)	33 *lb* 11.78 *oz*	36 *lb* 0.12 *oz*	37 *lb* 10.94 *oz*
Percentile-for-Net-Mass	**6.99**	**2.98**	**2.06**
Estimated-Adult Mass (*kg*)	47.12	44.98	41.99
Estimated-Adult Weight (*lb–oz*)	103 *lb* 14.49 *oz*	99 lb 2.97 *oz*	92 *lb* 9.48 *oz*
BMI**:** Body-Mass Index (kg/m^2)	14.04	13.59	12.63
Estimated-Adult BMI (kg/m^2)	19.23	18.80	17.54
Optimal Mass (*kg*)	16.13	17.41	19.53
Optimal Weight (*lb-oz*)	35 *lb* 9.16 *oz*	38 *lb* 6.22 *oz*	43 *lb* 0.96 *oz*
Δ Mass-for-Height (*kg*)	–0.83	–1.08	–2.44
Δ Weight-for-Height (*lb–oz*)	–1 *lb* 13.37 *oz*	–2 *lb* 6.10 *oz*	–5 *lb* 6.03 *oz*
Status (pertaining-to-mass)	5.16% WASTED	6.20% WASTED	12.49% WASTED

and random, is not as reliable as HBA_1C. When these moving profiles were generated for real-time data, these were termed as 'roadmaps'— *cf.* KJA Model, described later (Kamal *et al.*, 2013*c*).

The major contribution of KJR Model was replacement of concepts of growth (height) velocity and rate of mass gain (loss) by height- and mass-percentile trajectories (Kamal *et al.*, 2014*b*). For height or mass values falling below 3^{rd} percentile, logistic regression or, at times, linear interpolation was used to compute a numerical value of such percentile. Single-checkup-growth profile (for the final checkup) was computed using KJK (Kamal-Jamil-Khan) Model (Kamal *et al.*, 2011*b*). 'Growth Tables', obtained from 'Growth Charts', were used to compute growth-and-obesity profiles. It must be borne in mind that these charts are, officially, meant for assessment of American children. However, they are being used in other countries, where growth-and-obesity standards are not, still, developed. These profiles were used to evaluate the success of diet, exercise and lifestyle-adjustment plans. The method was general, and could be used for other populations, too, provided the dataset were replaced with population-representative growth tables. Some of the important concepts, which were mentioned in KJR Model (Kamal *et al.*, 2014*b*) and a subsequent seminar (Kamal, 2014) are summarized below:

Pseudo-Gain of Height or Mass (Weight): **'**Real-gain (-loss)' of height or mass (weight) occurs, when physical gain (loss) in height or mass is accompanied by a corresponding increase (decrease) in the respective percentile. On the other hand, 'pseudo-gain' means a physical gain in height (mass) over the period of study, associated with a percentile drop during the same period. In the example given, one notes gain of 4.22 *cm* in height of child from first to second checkup (104.40 *cm* to 109.62 *cm*), the height percentile dropped from 15.71 to 9.25 (pseudo-gain of height); mass increased from 15.30 *kg* to 16.33 *kg*, the mass percentile fell to 2.98 from 6.99 during the same period (pseudo-gain of mass). The later phenomenon continued from second to third checkup, with the mass percentile dropping to 2.06, when the child's actual mass increased to 17.09 *kg* (*cf*. Table 7[a]).

Under-Nutrition: 'Under-nutrition' is a combination of stunting and wasting. It is an acute condition, in which wasting exhibits a short-term response to inadequate dietary intake or episodes of infectious diseases, whereas, stunting is a chronic condition, which is a long-term representation of undernourishment as well as illnesses, which are persistent or repeated. In countries, which are poor in resources, malnutrition and infectious diseases are wide-

Table 8. Growth-and-Obesity Profiles of Y. L. (NGDS-BLA-2010-4663/A) exhibiting under-nutrition (coexistence of wasting and stunting)

Gender**:** Female • Date of Birth**:** 2005-01-14

Checkup	*1st*	*2nd*	*3rd*
Date of Checkup	2011-05-04	2012-03-19	2013-6-02
Age (*years*)	6.30	7.18	8.38
Dress Code	0/0.5	0/0.5	0/0.5
Cumulative-Scoliosis-Risk Weightage	1.50	3.50	9.25
Height (*cm*)	111.20	115.44	124.56
Height (*ft-in*)	3 *ft* 7.78 *in*	3 *ft* 9.45 *in*	4 *ft* 1.04 *in*
Percentile-for-Height	**14.57**	**9.31**	**20.07**
Estimated-Adult Height (*cm*)	156.22	154.69	157.67
Estimated-Adult Height (*ft–in*)	5 *ft* 1.50 *in*	5 *ft* 0.90 *in*	5 *ft* 2.07 *in*
Gross Mass (*kg*)	16.30	16.99	18.59
Clothing Correction (*kg*)	0	0	0
Net Mass (*kg*)	16.30	16.99	18.59
Net Weight (*lb-oz*)	35 *lb* 15.06 *oz*	37 *lb* 7.30 *oz*	40 *lb* 15.86 *oz*
Percentile-for-Net-Mass	**2.85**	**2.17**	**1.86**
Estimated-Adult Mass (*kg*)	44.56	42.34	41.34
Estimated-Adult Weight (*lb–oz*)	98 *lb* 3.92 *oz*	93 *lb* 5.91 *oz*	91 *lb* 2.52 *oz*
BMI**:** Body-Mass Index (kg/m^2)	13.18	12.75	11.98
Estimated-Adult BMI (kg/m^2)	18.26	17.70	16.63
Optimal Mass (*kg*)	18.07	19.22	23.32
Optimal Weight (*lb-oz*)	39 *lb* 13.36 *oz*	42 *lb* 6.13 *oz*	51 *lb* 6.87 *oz*
Δ Mass-for-Height (kg)	–1.77	–2.23	–4.73
Δ Weight-for-Height (*lb–oz*)	–3 *lb* 14.30 *oz*	–4 *lb* 14.72 *oz*	–10 *lb* 7.01 *oz*
Status (pertaining-to-mass)	9.77% WASTED	11.61% WASTED	20.30% WASTED

spread. The conditions of stunting and wasting are found frequently, because gain of weight and processes of catch-up growth are hindered. In addition to monitoring of height and weight, mid-upper-arm-circumference measurements may, also, point to under-nutrition (*cf.* Figure 5). The example given in Table 8[a] lists growth-and-obesity data of a child, whose height percentile, $P(h)$, is located below 25 (NCHS 50^{th} percentile is mapped to Pakistani 100^{th} percentile) and mass percentile, $P(\mu) < P(h)$, exhibiting the phenomenon of under-nutrition.

*Over-Nutrition***:** 'Over-nutrition' is the coexistence of obesity and tallness. It might be the result of simple obesity due to over-eating. This condition may be a healthier combination as compared to stunting with wasting, stunting with obesity and tallness with wasting, as long as the person is not over-fat, as determined by waist and hip circumferences. The key hormone involved in growth processes is 'growth hormone'. It has two main functions in the body. Its primary role lies in gain of height. Further, it maintains muscularity in the body (Cuneo *et al.*, 1991). For tall children, the overweight condition is, more likely, due to excessive muscle mass, and not due to excessive fat.

Fig. 5. Mid-upper-arm circumference of a girl measured in SF-Growth-and-Imaging Laboratory (http://www.ngds-ku.org/Papers/J34/Fig_5.htm)

Table 9. Growth-and-Obesity Profiles of L. Z. (NGDS-BLA-2011-5822/G) exhibiting over-nutrition (coexistence of obesity and tallness)

Gender**:** Male • Date of Birth**:** 2005-11-02

Checkup	1^{st}	2^{nd}
Date of Checkup	2012-05-02	2013-11-26
Age (*years*)	6.50	8.07
Dress Code	0/0.5	0/0.5
Cumulative-Scoliosis-Risk Weightage	6.00	7.25
Height (*cm*)	120.03	129.02
Height (*ft-in*)	3 *ft* 11.26 *in*	4 ft 2.80 in
Percentile-for-Height	**60.24**	**54.84**
Estimated-Adult Height (*cm*)	178.71	177.67
Estimated-Adult Height (*ft–in*)	5 *ft* 10.36 *in*	5 *ft* 9.95 *in*
Gross Mass (*kg*)	23.87	31.68
Clothing Correction (*kg*)	0	0
Net Mass (*kg*)	23.87	31.68
Net Weight (*lb-oz*)	52 *lb* 10.13 *oz*	69 *lb* 13.67 *oz*
Percentile-for-Net-Mass	**71.46**	**86.18**
Estimated-Adult Mass (*kg*)	77.96	86.36
Estimated-Adult Weight (*lb–oz*)	171 *lb* 14.57 *oz*	190 *lb* 6.67 *oz*
BMI**:** Body-Mass Index (kg/m^2)	16.57	19.03
Estimated-Adult BMI (kg/m^2)	24.41	27.36
Optimal Mass (*kg*)	22.82	26.43
Optimal Weight (*lb-oz*)	50 *lb* 4.93 *oz*	58 lb 4.32 oz
∆ Mass-for-Height (*kg*)	+1.05	+5.25
∆ Weight-for-Height (*lb–oz*)	+2 *lb* 5.20 *oz*	+11 *lb* 9.35 *oz*
Status (pertaining-to-mass)	4.62% OBESE	19.88% OBESE

'Over-nutrition' might, also, be the cause of tallness plus obesity. Both tissue-synthesis rate and amount of storage in body are amplified in this phenomenon. It must be realized that, over-fat or obesity are conditions not good for health, whether or not tallness is associated with them. The example given in Table 9[a] lists growth-and-obesity data of a child, whose height was lying above 50^{th} percentile and $P(\mu) > P(h)$, exhibiting the phenomenon of over-nutrition.

*Acute Malnutrition***:** 'Acute malnutrition', causing frequent illnesses during childhood period, may result in wasting, and its persistence at times produces stunting (Richard *et al.*, 2012; Kamal *et al.*, 2014*b*). Figure 6 shows a patient, exhibiting the phenomenon of acute malnutrition, who has gone over multiple cardiac surgeries. The example

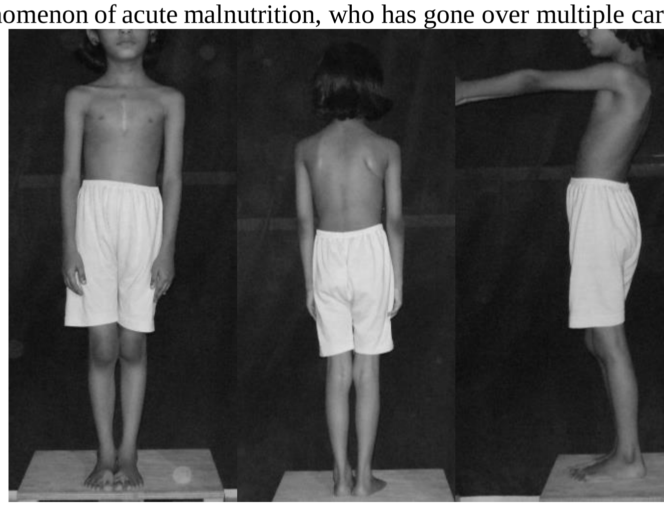


Fig. 6. Patient exhibiting the phenomenon of acute malnutrition, due to impaired cardiac function, whose growth is monitored in SF-Growth-and-Imaging Laboratory (http://www.ngds-ku.org/Papers/J34/Fig_6.htm)

Table 10. Growth-and-Obesity Profiles of Z. L. (NGDS-BLA-2011-5748/E) exhibiting acute malnutrition (severe stunting and wasting)

Gender: Male • Date of Birth: 2005-04-08

Checkup	*1st*	*2nd*
Date of Checkup	2012-04-26	2013- 11- 28
Age (*years*)	7.05	8.64
Dress Code	0/0.5	0/0.5
Cumulative-Scoliosis-Risk Weightage	6.0	7.0
Height (*cm*)	110.15	117.05
Height (*ft-in*)	3 *ft* 7.37 *in*	3 *ft* 10.08 *in*
Percentile-for-Height	**2.01**	**1.37**
Estimated-Adult Height (*cm*)	160.90	159.38
Estimated-Adult Height (*ft–in*)	5 *ft* 3.35 *in*	5 *ft* 2.75 *in*
Gross Mass (*kg*)	16.77	19.09
Clothing Correction (*kg*)	0	0
Net Mass (*kg*)	16.77	19.09
Net Weight (*lb-oz*)	36 *lb* 15.65 *oz*	42 *lb* 1.50 *oz*
Percentile-for-Net-Mass	**1.61**	**1.48**
Estimated-Adult Mass (*kg*)	49.36	48.93
Estimated-Adult Weight (*lb–oz*)	108 *lb* 13.36 *oz*	107 *lb* 14.28 *oz*
BMI: Body-Mass Index (kg/m^2)	13.82	13.93
Estimated-Adult BMI (kg/m^2)	19.07	19.26
Optimal Mass (*kg*)	17.21	18.93
Optimal Weight (*lb-oz*)	37 *lb* 15.20 *oz*	41 *lb* 11.96 *oz*
Δ Mass-for-Height (*kg*)	–0.44	+0.16
Δ Weight-for-Height (*lb–oz*)	–15.55 *oz*	+5.54 *oz*
Status (pertaining-to-mass)	2.56% WASTED	0.83% OBESE

given in Table 10[a] lists growth-and-obesity data of a child, whose height and mass percentiles both fell below 3, exhibiting the phenomenon of severe wasting and stunting.

Energy-Channelization Problem: The coexistence of stunting and obesity may be indicative of hormonal problems, in particular, deficiency of growth hormone. Another reason could be that most of the nutrients are taken up in the process of weight gain instead of tissue synthesis (the process of height gain). Chianese (2005), remarked "obesity in a short child increases suspicion of endocrine or genetic disorders". Impaired oxidation is one of the many predictors of obesity (Hoffman *et al.*, 2000). Correlation of impaired oxidation is established with stunting. A Brazilian study showed that stunted children had a tendency to gain more weight over time as compared to non-stunted children, in case they, persistently, consumed high-fat food (Sawaya *et al.*, 1997). There are very rare studies dealing with association between tallness and wasting. However, the NGDS Team found several such cases, which indicated co-existence of tallness and wasting. Even when a child is doing well in terms of height gain, it is imperative to monitor gain of weight. It might happen that most nutrients, taken up by the body, are consumed in height gain. Hence, the assimilation of nutrients may fall below the threshold to meet daily requirements, causing wasting. There may, also, be the phenomenon of mal-absorption in individuals, who are underweight, although they are consuming proper food. A proper assimilation of nutrients is, sometimes, hindered by food allergies, inflammation in intestine, hidden ulcers and gluten intolerance. This phenomenon may, also, be considered a chronic condition. In fact, an adequate amount of body fat is required for heat insulation, to act as energy storehouse and to prevent bone fractures. Stunting with obesity and tallness with wasting, both conditions might be exhibited due to 'energy-channelization problem' in the human body. For a person, the two critical periods in terms of weight management (Dietz, 1994; Lawlor and Chaturvedi, 2006; Anderson *et al.*, 2012) and gaining of height (Karlberg, 1987; 2004) are infancy and adolescence. There is, therefore, a need of height and weight monitoring during these age intervals. Growing children require positive-energy balance — more energy gained through rich food (intake) than expenditure through physical activity (output). However, monitoring is needed to ensure that this excess energy is properly channelized towards tissue synthesis (height gain) and not towards extra gaining of weight. Efficient and effective diet-and-exercise plans should be developed to achieve these objectives. Diet plan should consist of those

Table 11. Growth-and-Obesity Profiles of H. A. (NGDS-BLA-2010-4795/F)
exhibiting energy channelization (coexistence of wasting and tallness)

Gender**:** Female • Date of Birth**:** 2006-04-05

Checkup	*1st*	*2nd*	*3rd*
Date of Checkup	2011-04-21	2012-04-11	2013-05-17
Age (*years*)	5.04	6.02	7.12
Dress Code	0/0.5	0/0.5	0/0.5
Cumulative-Scoliosis-Risk Weightage	3.50	7.00	11.50
Height (*cm*)	111.50	117.55	124.56
Height (*ft-in*)	3 *ft* 7.90 *in*	3 ft 10.28 in	4 *ft* 1.04 *in*
Percentile-for-Height	**68.49**	**69.09**	**65.34**
Estimated-Adult Height (*cm*)	180.29	166.67	166.01
Estimated-Adult Height (*ft–in*)	5 *ft* 10.98 *in*	5 *ft* 5.62 *in*	5 *ft* 5.36 *in*
Gross Mass (*kg*)	15.30	18.76	22.09
Clothing Correction (*kg*)	0	0	0
Net Mass (*kg*)	15.30	18.76	22.09
Net Weight (*lb-oz*)	33 *lb* 11.78 *oz*	41 *lb* 5.85 *oz*	48 *lb* 11.34 *oz*
Percentile-for-Net-Mass	**5.52**	**29.22**	**38.96**
Estimated-Adult Mass (*kg*)	55.94	53.45	55.68
Estimated-Adult Weight (*lb–oz*)	123 *lb* 5.71 *oz*	117 *lb* 13.60 *oz*	122 *lb* 12.50 *oz*
BMI**:** Body-Mass Index (kg/m^2)	12.31	13.58	14.24
Estimated-Adult BMI (kg/m^2)	17.21	19.24	20.20
Optimal Mass (*kg*)	19.81	22.05	24.82
Optimal Weight (*lb-oz*)	43 *lb* 10.75 *oz*	48 *lb* 9.97 *oz*	54 *lb* 11.77 *oz*
Δ Mass-for-Height (*kg*)	–4.51	–3.29	–2.73
Δ Weight-for-Height (*lb–oz*)	–9 *lb* 14.97 *oz*	–7 *lb* 4.11 *oz*	–6 *lb* 0.43 *oz*
Status (pertaining-to-mass)	22.75% WASTED	14.93% WASTED	11.01% WASTED

nutrients, which help in gaining height and healthy weight. This plan should discourage fat accumulation in body. Exercises, suitable to the physique of child, should be introduced (Kamal and Khan, 2013; 2014). Table 11[a] illustrates 'energy-channelization problem', exhibiting tallness combined with wasting (*cf*. Figure 7*a*), which might be the result of micronutrients, predominantly, involved in tissue synthesis, all of them flowing through a single absorption-channel. The other manifestation of 'energy-channelization problem' is stunting combined with obesity (*cf*. Figure 7*b*), which may due to storage of most micronutrients, all of them flowing through one channel of absor-

Fig. 7. Children exhibiting the phenomenon of energy channelization, (*a*) tallness with wasting and (*b*) stunting with obesity, monitored in SF-Growth-and-Imaging Laboratory (http://www.ngds-ku.org/Papers/J34/Fig_7.htm)

Table 12. Growth-and-Obesity Profiles of R. Z. (NGDS-BLA-2010-5280/F) exhibiting energy channelization (coexistence of obesity and stunting)

Gender**:** Female • Date of Birth**:** 2005-08-17

Checkup	*1st*	*2nd*	*3rd*
Date of Checkup	2011-04-21	2012-04-16	2013-05-17
Age (*years*)	5.68	6.66	7.75
Dress Code	0/0.5	0/0.5	0/0.5
Cumulative-Scoliosis-Risk Weightage	0.50	5.00	8.50
Height (*cm*)	107.40	112.83	118.24
Height (*ft-in*)	3 *ft* 6.28 *in*	3 *ft* 8.42 *in*	3 *ft* 10.55 *in*
Percentile-for-Height	**16.19**	**11.20**	**8.21**
Estimated-Adult Height (*cm*)	156.65	155.33	154.17
Estimated-Adult Height (*ft–in*)	5 *ft* 1.67 *in*	5 *ft* 1.15 *in*	5 *ft* 0.70 *in*
Gross Mass (*kg*)	17.80	19.40	22.20
Clothing Correction (*kg*)	0	0	0
Net Mass (*kg*)	17.80	19.40	22.20
Net Weight (*lb-oz*)	39 *lb* 3.98 *oz*	42 *lb* 12.43 *oz*	48 *lb* 15.22 *oz*
Percentile-for-Net-Mass	**25.73**	**20.65**	**23.70**
Estimated-Adult Mass (*kg*)	52.65	51.29	52.12
Estimated-Adult Weight (*lb–oz*)	116 *lb* 1.37 *oz*	113 *lb* 1.58 *oz*	114 *lb* 14.89 *oz*
BMI**:** Body-Mass Index (kg/m^2)	15.43	15.24	15.88
Estimated-Adult BMI (kg/m^2)	21.45	21.26	21.93
Optimal Mass (*kg*)	17.00	18.45	20.18
Optimal Weight (*lb-oz*)	37 *lb* 7.68 *oz*	40 *lb* 10.92 *oz*	44 *lb* 7.94 *oz*
Δ Mass-for-Height (*kg*)	+0.80	+0.95	+2.02
Δ Weight-for-Height (*lb–oz*)	+1 *lb* 12.31 *oz*	+2 *lb* 1.51 *oz*	+4 *lb* 7.27 *oz*
Status (pertaining-to-mass)	4.72% OBESE	5.15% OBESE	10.01% OBESE

ption. Table 12[a] lists clinical data of a child, who is obese and stunted.

Figure 8 depicts these 4 phenomena as intersections of 4 sets, in the form of Venn diagrams — set of stunted children, set of tall children, set of wasted children and set of obese children. Intersection of 1st and 3rd sets manifested 'under-nutrition', that of 2nd and 4th 'over-nutrition', whereas the intersections of 1st and 4th as well as 2nd and 3rd both exhibited 'energy-channelization problem'. This diagram first appeared in a paper published in the same journal (Kamal *et al.*, 2014*b*).

Fig. 8. Venn-diagram (set-theoretic) representation of 'under-nutrition', 'over-nutrition' and 'energy-channelization problem' (http://www.ngds-ku.org/Papers/J34/Fig_8.htm)

Table 13. Growth-and-Obesity Profiles of G. M. T. (NGDS-BLA-2010-5331/F) exhibiting puberty-induced energy channelization

Gender: Female • Date of Birth: 2005-09-15

Checkup	*1st*	*2nd*	*3rd*
Date of Checkup	2011-04-21	2012-04-16	2013-05-17
Age (*years*)	5.60	6.59	7.67
Dress Code	0/0.5	0/0.5	0/0.5
Cumulative-Scoliosis-Risk Weightage	2.00	4.50	8.00
Height (*cm*)	120.40	126.34	132.33
Height (*ft-in*)	3 *ft* 11.40 *in*	4 *ft* 1.74 *in*	4 *ft* 4.10 *in*
Percentile-for-Height	**94.83**	**91.10**	**86.22**
Estimated-Adult Height (*cm*)	173.87	172.13	170.63
Estimated-Adult Height (*ft–in*)	5 *ft* 8.45 *in*	5 *ft* 7.77 *in*	5 *ft* 7.18 *in*
Gross Mass (*kg*)	28.80	22.92	36.99
Clothing Correction (*kg*)	0	0	0
Net Mass (*kg*)	28.80	22.92	36.99
Net Weight (*lb-oz*)	63 *lb* 8.06 *oz*	50 *lb* 8.62 *oz*	81 *lb* 9.01 *oz*
Percentile-for-Net-Mass	**98.61**	**61.88**	**97.28**
Estimated-Adult Mass (*kg*)	94.49	61.88	90.01
Estimated-Adult Weight (*lb–oz*)	208 *lb* 5.74 *oz*	136 *lb* 7.14 *oz*	198 *lb* 7.41 *oz*
BMI**:** Body-Mass Index (kg/m^2)	19.87	14.36	21.12
Estimated-Adult BMI (kg/m^2)	31.26	20.89	30.92
Optimal Mass (*kg*)	25.68	27.78	30.62
Optimal Weight (*lb-oz*)	56 *lb* 9.97 *oz*	61 *lb* 4.16 *oz*	67 *lb* 8.15 *oz*
Δ Mass-for-Height (*kg*)	+3.12	–4.86	+6.37
Δ Weight-for-Height (*lb–oz*)	+6 lb 14.09 *oz*	–10 *lb* 11.55 *oz*	+14 *lb* 0.86 *oz*
Status (pertaining-to-mass)	12.15% OBESE	17.50% WASTED	20.82% OBESE

*Puberty-Induced Energy-Channelization***:** The example given in Table 13[a] lists growth-and-obesity data of a girl, who was entering puberty and exhibited the phenomenon of 'puberty-induced energy-channelization', associated with drops in percentiles of both height and mass at the time, when she presented herself for her second checkup (April 16, 2012). A pickup in mass percentile was noticed at the time of her third checkup (May 17, 2013).

KJK Model

In KJK (Kamal-Jamil-Khan) Model (Kamal *et al.*, 2011*b*), 'Growth-and-Obesity Profile' of a family was determined by first converting dates of birth and dates of measurement in fractional form and computing age as their difference. Father's (mother's) height and mass percentiles were taken as boy's (girl's) at the age of 20 *years*. Percentiles corresponding to lower and higher values of height tabulated were used in the equation of straight line (2-point form). Once the height percentile, $P(h)$, was available, mass corresponding to this percentile was determined as 'optimal mass', μ_{opt}. If net mass, μ, was more (less) than the optimal mass, the person was considered as obese (wasted). Percentile corresponding to height (mass) of child was determined by first computing heights at the given age, which were lesser and greater than the measured height (mass) using linear interpolation. Once the upper and the lower bounds were available at the given age, required percentile was determined by another linear interpolation (constant-age route). As soon as these percentiles were available, a qualitative judgment could be made. If the height percentile was lesser (greater) than the mass percentile, the child was considered as obese (wasted). Similarly, if the height percentile was greater (lesser) than the target-height percentile, the child was considered as stunted (tall). 2 routes, constant age or constant percentile, were, also, available for computation of optimal mass. Both of these routes gave identical results, which was verified in numerical examples. Obesity profile was, then, determined, giving status, pertaining-to-mass, expressed as a percentage. A similar method was used to compute mid-parental height at current age, based on the percentile obtained earlier. A comparison of measured, h, and current-age-mid-parental, h_{MP}, heights indicated if the child was stunted (tall). Status, pertaining-to-height, could be expressed as a percentage. This mathematical-statistical method was termed as 'Box Interpolation', which worked well when the height and mass percentiles, both, were between 3 and 97.

KJ Model

Box interpolation was employed to compute percentiles corresponding to father's and mother's heights — linear interpolation could not be used as parents were still growing in KJ (Kamal-Jamil) Model (Kamal and Jamil, 2012). These percentiles were used to determine estimated-adult height of each parent through linear interpolation from heights at age 20 read from respective gender-specific table. These were, then, used in place of real-time measured heights of parents depending on whether one wants to compute target height of a boy or a girl. Rest of the procedure was identical to the one described for KJK model.

KJA Model

The KJA (Kamal-Jamil-Ansari) Model (Kamal *et al.*, 2013*c*) generalized KJK Model (Kamal *et al.*, 2011*b*), to generate real-time 'Growth-and-Obesity Roadmaps' — a generalization of the moving-profile concept, presented elsewhere (Kamal *et al.*, 2014*b*). Target-height (adult-mid-parental-height) percentiles were evaluated following procedures used for obtaining parental-height percentiles. Son's or daughter's height (mass) percentile was computed by first determining height at the given age using box-interpolation technique. Constant-age route was used to calculate optimal mass and, then, generate obesity profile. Mid-parental height at current age was computed following a similar procedure. A comparison of measured height and current-age-mid-parental height determined if the child was tall or stunted, with 1% tolerance. 'Growth-and-Obesity Roadmap' of a child was prepared by tabulating more than one profiles (corresponding to various checkups), and including quantitative recommendations to increase height and gain or lose mass (weight), which could be computed from the most-recent profile. The reference height was taken as maximum of current-age-mid-parental height, army-cutoff height and measured height. Optimal mass was calculated, accordingly, 6 *months* down the road, estimated value of reference height after 6 *months*. To compute these roadmaps, software was developed and tested by running more than 1500 cases. If the software suggested losing weight, it was recommended not to lose more than one pound per week. Losing weight rapidly might deteriorate health of a child.

KAJ Model

KAJ (Kamal-Ansari-Jamil) Model was an enhancement of the above model to include month-wise recommendations for picking up height and gaining/losing weight as well as optimal-mass equivalent for above-30 individuals (Kamal *et al.*, 2014*a*).

ESTIMATED-ADULT BMI

In 2012, 'estimated-adult BMI' was defined (Kamal and Jamil, 2012). It gave a snapshot of obesity status of children, when they would be fully grown. The index was computed by replacing mass and height of a child by the respective estimated-adult values, $\mu_{\text{est-adult}}$ and $h_{\text{est-adult}}$ Mathematically,

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

The strength of this index was that it could be interpreted on the basis of prevailing adult scales, alerting school health team to trends of obesity in students. Tables 5[a] and 6[a] show numerical values of *estimated-adult BMI*, computed from estimated-adult height and estimated-adult mass.

OPTIMAL MASS (WEIGHT), WASTING AND OBESITY

The concept of 'optimal mass' was used for the first time in 2004 (Kamal *et al.*, 2004). However, a rigorous definition was provided in 2011 (Kamal *et al.*, 2011*b*) and elaborated in a subsequent presentation (Kamal *et al.*, 2013*b*). Optimal mass, μ_{opt}, was defined as the mass corresponding to height percentile. Mathematically,

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

$P(\mu_{\text{opt}})$ represents percentile of optimal mass. A person was wasted, when the incumbent had lesser mass-for-height, whereas an obese person had excess mass-for height. In terms of optimal mass, if the mass of a child was lesser than optimal mass, then the child was wasted; whereas if it exceeded optimal mass, the child was obese**:**

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

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

The status was computed, taking optimal mass as reference (Kamal *et al.*, 2011*b*), which gave quantitative estimates of wasting and obesity**:**

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

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

1% variation from optimal mass (end points included) was considered normal.

The procedure for calculation of optimal mass was based on the underlying assumption that for an ideal human body, percentiles of height and mass must, exactly, match. This made sense from the view that a child's performance on mass curve should replicate the performance on height curve. However, the physiological basis of this hypothesis needs to be studied.

Kamal *et al.* (2011*a*) reported a high prevalence of wasting among BS (Final Year) students of University of Karachi. Tables 5[a] and 6[a] contain numerical examples of statuses pertaining to mass, for wasted and obese children.

COMPUTATIONAL PROBLEM OF EXTREME CASES

For children on growth extremes, heath-and-nutrition assessment becomes extremely important, as they may need special intervention from nutritional-and-medical points of view. Certain diseases, *e. g.*, acromegaly and hyper-insulinism, at times appear as excessive gain of height during childhood. In contrast, overactive thyroid, some hidden ulcers and even some cancers, exhibit in early stages as falling short on height trajectory or failure to gain weight. The methods to deal with extreme cases (percentiles below 3$^{\text{rd}}$ or above 97$^{\text{th}}$), described in an earlier work (Kamal and Jamil, 2012), gave upper or lower values for height and mass statuses as well as for estimated-adult BMI. However, there, still, remains a dire need to precisely evaluate these parameters.

Techniques to create growth-and-obesity profiles of extreme cases were developed by extending CDC charts beyond the percentile interval $(3 \le P \le 97)$. This extrapolation was made possible by 'KJ-Regression Model', described in the next section.

KJ-REGRESSION MODEL

KJ-Regression Model was constructed using height-versus-percentile data and. subsequently, tested for adequacy through residual analysis, which was carried out using Minitab. The program calculated 'co-efficient of determination'. This coefficient determined the proportion of variation in the data, explained by the models. This was required to evaluate the validity of extrapolated values, for 0.01$^{\text{th}}$, 0.1$^{\text{th}}$, 1$^{\text{st}}$, 99$^{\text{th}}$, 99.9$^{\text{th}}$ and 99.99$^{\text{th}}$ percentiles. The exercise was repeated, using Minitab, for data set of mass percentiles for a certain age. It was found not easy to handle such a large data set to construct 128 (*i. e.*, 74 + 74) models using that software. A program was written in C#, which computed regression-model statistics. These statistics were fitted to the data, available for different ages. Extrapolated values for different ages were used to construct 'extended growth charts'.

Height-Percentile-Regression Models

Analysis of some plots between heights and percentiles revealed a curvilinear shape of these plots. Application of transformation to percentile data made the transformed percentile values, almost, linearly related to height**:**

(9) $$Logit(p) = \ln\left(\frac{p}{100 - p}\right)$$

The correlation between height, at different ages, and the transformed percentile values, *Logit*(*p*) was found to be between 0.99906 and 0.99938 for girls. For boys, the correlation varied from 0.99907 to 0.99938. Equation (10) was used to fit a transformed-linear-regression modeled to height-percentile data**:**

(10) $$h = \alpha + \beta Logit(p)$$

where *h* symbolized height in *cm*, at a given age. The parameters α and β represented *y* intercept and slope of the linear-regression model, the first one was in the range 84.97-163.31 for girls and 86.46-176.80 for boys, whereas the second one in the range 1.93-4.14 for girls and 1.94-4.49 for boys. According to the results obtained through C# program, *Logit*(*p*) explained 99% of height variation —99.81-99.87% for girls and 99.81-99.87% for boys.

Mass-Percentile-Regression Models

A similar analysis of plots between masses and percentiles was done. The same transformation, previously applied to height percentiles, was applied to these data. In addition, the mass variable of log (natural) transformed. Application of these two transformations to mass-percentile data, also, made the graph, almost, linear. The correlation between $ln(\mu)$, at different ages, and the transformed percentile values, *Logit*(*p*) was found to be between 0.9883 and 0.9887 for girls, according to results of the C# program. For boys, the correlation varied from 0.9938 to 0.9992. Equation (10) was used to fit a transformed-linear-regression model fitted to height-percentile data**:**

$$\ln(\mu) = \gamma + \delta Logit(p) \quad (11)$$

where μ symbolized mass in *kg*, at a given age. The parameters γ and δ represented *y* intercept and slope of the linear-regression model, the first one was in the range 2.49-4.11 for girls and 2.56-4.28 for boys, whereas the second one in the range 0.061-0.116 for girls and 0.061-0.112 for boys. According to the results obtained through C# program, *Logit*(*p*) explained 99% of height variation —97.68-99.75% for girls and 98.78-99.84% for boys. **Additional File 1** (http://www.ngds-ku.org/Papers/J34/Additional_File_1.pdf) describes these models in detail.

Application to Clinical Cases

Extreme cases reported earlier (Kamal and Jamil, 2012) are processed using KJ-Regression Model and compiled in **Additional File 2** (http://www.ngds-ku.org/Papers/J34/Additional_File_2.pdf).

GROWTH CHARTS AND TABLES

Pakistani Growth Charts and Tables

Although some quarters argue against localized standards, the changes in body composition with environmental and geographic and conditions may not be properly accounted for by a single standard, which can be applied globally. This is the reason to develop and update ethnicity-specific-growth charts by different countries. In the absence of these charts, NCHS data are used to interpret the results (Ayatollahi, 1993), sometimes with statistical adjustment (Abolfotouh *et al.*, 1993; Al-Frayh and Bamgboye, 1993).

Aziz *et al.* (2012) conducted a cross-sectional descriptive survey to prepare height-for-age and weight-for-age centile charts for 2-16-*year*-old children, using multistage stratified sampling from the Pakistani population, during the period 2006-9 (sample size 12837). However, the factors, which influence, height and weight measurement were not considered in the study, *e. g.*, the conditions under which, height and weight were measured, the time of the day (morning or evening), clothing worn by the child during weight measurement, errors due to inter-observer and intra observer variations in reproducibility, accuracy and precision. An improved version of growth charts could be generated by employing standardized procedures (Kamal, 2006; Kamal *et al.*, 2013*d*; Kamal and Razzaq, 2014).

Mushtaq *et al.* (2012) made another attempt to prepare the Pakistani Growth Charts, by listing age- and gender-specific smoothed heights, weights BMI percentiles for the Pakistani school children in the age range 5-12 years-aged. The technique employed was multistage cluster sampling (sample size**:** 1860; boys 977 and girls 883) in Lahore, Punjab, Pakistan. 50^{th}-height-percentile curves for WHO 2007 and CDC 2000 references was compared with the study sample under study. The conclusion was that the Pakistani school-aged children differed, significantly, from WHO and CDC references. The techniques of sampling, the protocols for anthrpometric measurements and the statistical methods used in this study were better than those employed in the previous study (Aziz *et al.*, 2012). However, the scope of data collection was limited, as only one metropolis of Pakistan (Lahore) was the source of data generation. It is true that a large number of different ethnicities are living in the provincial capital, the data are not diversified enough to represent the entire Pakistani population, which has rural and urban population and five provinces.

Extension of CDC Growth Charts and Tables

The ‘Extended Growth Tables’ (with could be used to deal with extreme cases, as they contain trajectories corresponding to 0.01^{th}, 0.1^{th}, 1^{st}, 99^{th}, 99.9^{th} and 99.99^{th} percentiles, in addition to 5-decimal values of heights and

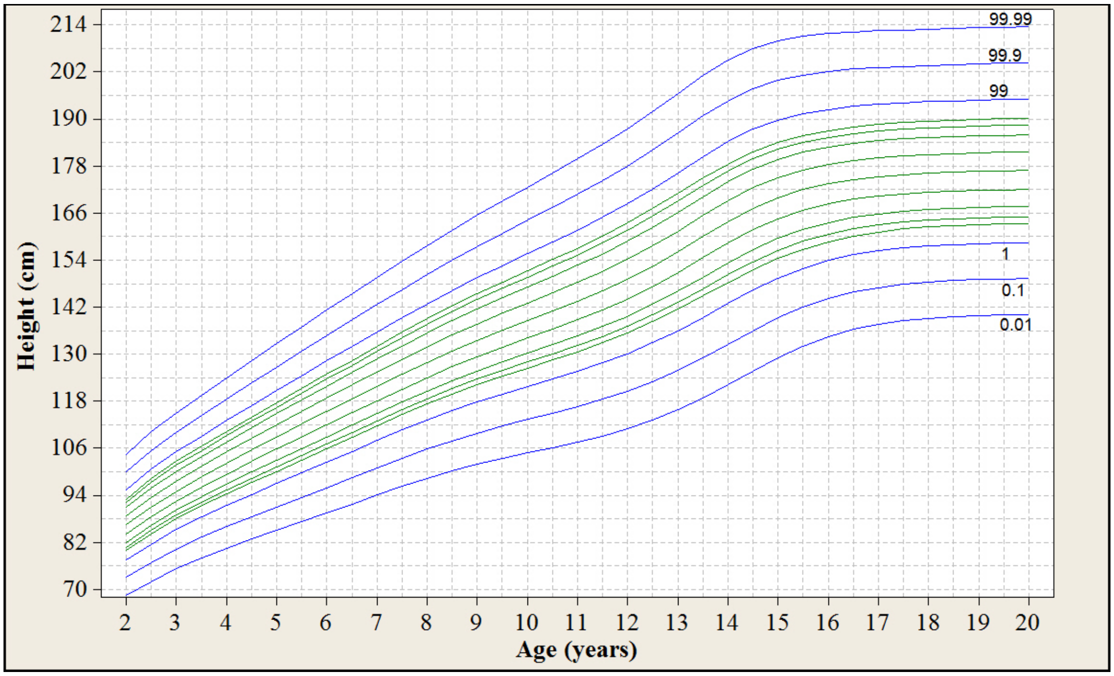


Fig. 9. Growth charts for boys, representing their heights in the age range 2-20 years, with additional trajectories corresponding to 0.01th, 0.1th, 1st, 99th, 99.9th and 99.99th percentiles (http://www.ngds-ku.org/Papers/J34/Fig_9.htm)

masses in the range 3rd to 97th percentile) and the corresponding 'Extended Growth Charts' were generated from the growth charts released by CDC[f]. As per convention, all ages are reported in *years*, heights in *cm* and masses in *kg*. Figures 9 and 10 show height and mass extended charts for boys, with extreme percentiles (larger-size version of these charts and extended growth tables appear in **Additional File 3**, which is, uploaded, at the following address**:**

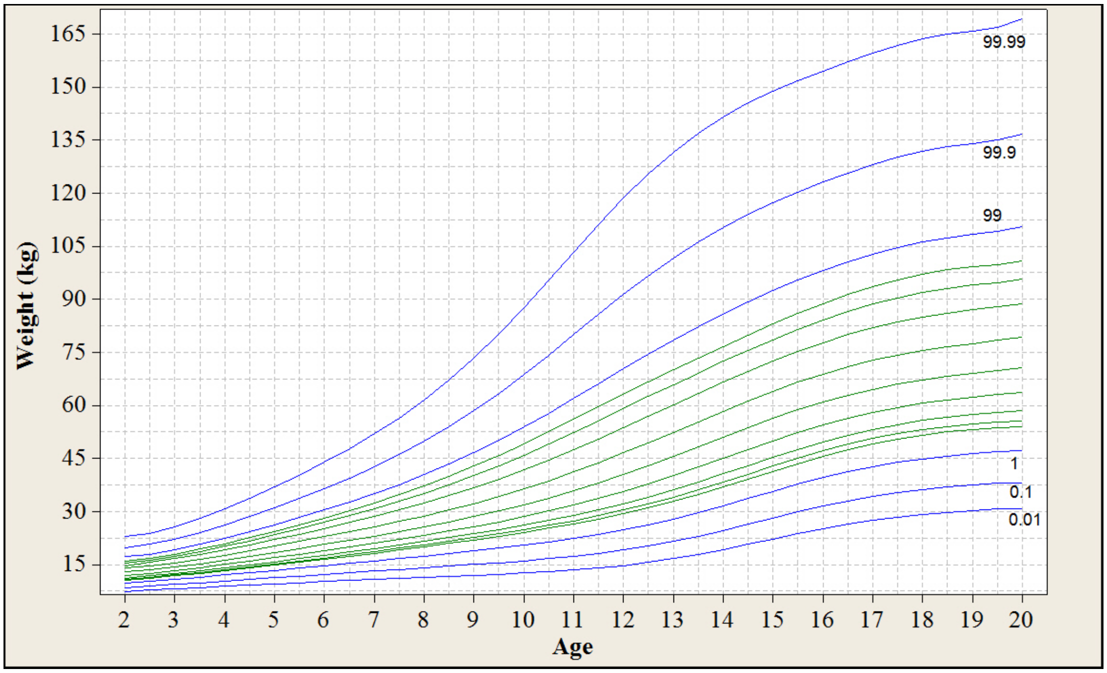


Fig. 10. Growth charts for boys, representing their masses in the age range 2-20 years, with additional trajectories corresponding to 0.01th, 0.1th, 1st, 99th, 99.9th and 99.99th percentiles (http://www.ngds-ku.org/Papers/J34/Fig_10.htm)

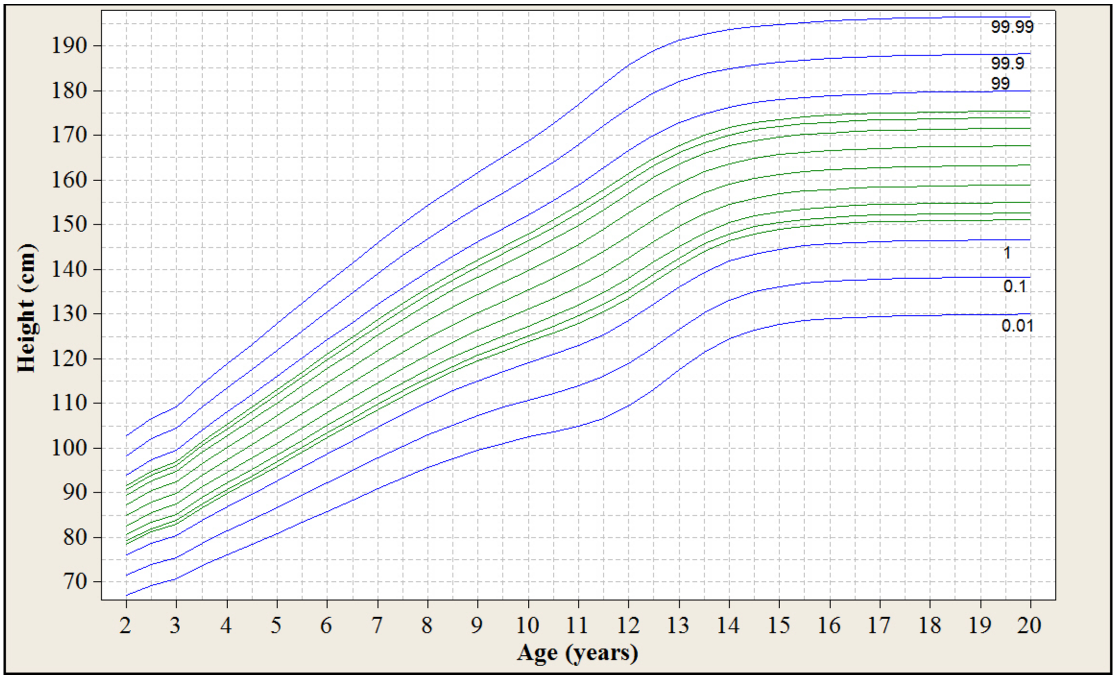


Fig. 11. Growth charts for girls, representing their heights in the age range 2-20 years, with additional trajectories corresponding to 0.01th, 0.1th, 1st, 99th, 99.9th and 99.99th percentiles (http://www.ngds-ku.org/Papers/J34/Fig_11.htm)

http://www.ngds-ku.org/Papers/J34/Additional_File_3.pdf. Figures 11 and 12 show similar charts for girls.

CONCLUSION AND FUTURE DIRECTIONS

Computation of optimal mass for extreme cases, in which percentiles of height, mass or mid-parental height lie below 3 or above 97, is an amalgamation of basic and clinical sciences, and may have the potential of greatest

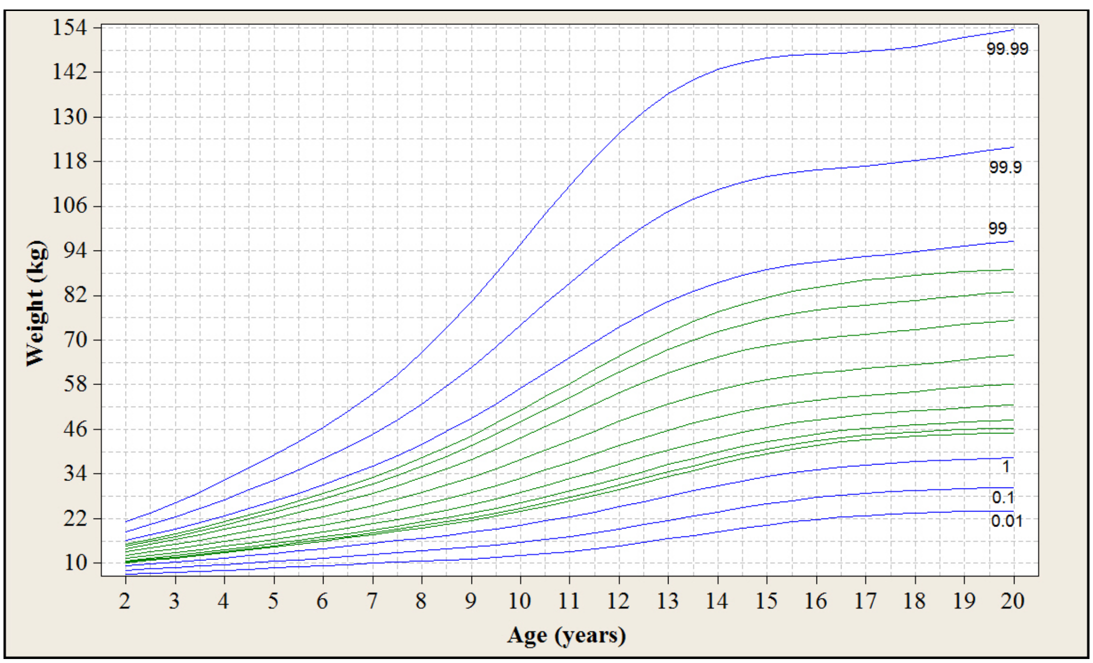


Fig.12. Growth charts for girls, representing their masses in the age range 2-20 years, with additional trajectories corresponding to 0.01th, 0.1th, 1st, 99th, 99.9th and 99.99th percentiles (http://www.ngds-ku.org/Papers/J34/Fig_12.htm)

benefit to mankind, provided the problem were investigated from multiple perspectives by providing rationale for optimal mass, not only, from mathematics, but also, from biophysics (Apell *et al.*, 2011) and physiology. The adverse implications of obesity pointed out by Ludwig (2007) take the matter of optimal mass to the forefront of discovery challenges. Management of optimal mass was suggested to be the 'optimal solution' among diet plan (Kamal *et al.*, 2013*b*), exercise plan and lifestyle adjustment (Kamal and Shahid, 2013; 2014). During the preceding year and this year, our group tackled the issue of determining optimal mass-for-height by developing child growth-and-obesity models, foremost among them were KJA Model (Kamal *et al.*, 2013*c*), KJR Model (Kamal *et al.*, 2014*b*), KAJ Model (Kamal *et al.*, 2014*a*), and KJ-Regression Model, the last one proposed in this work. The above models introduced**:** (*i*) 'Optimal Mass' — mass corresponding to percentile of height; (*ii*) 'Status (pertaining-to-mass)' — the ratio of absolute difference of mass and optimal mass to optimal mass, expressed as percentage and (*iii*) 'Estimated-Adult *BMI*' — the index generated by replacing mass and height by estimated-adult mass and estimated-adult height, respectively, to compute *BMI*. These parameters need to be validated with respect to agreed-upon standard, 'body-mass index' (*BMI*). Studies should be conducted to classify adults and children as obese and wasted, independently, by determining correlation between each of the following pairs**:**

a) *BMI* and optimal mass for individuals above the age of 20
b) *BMI* and status (pertaining-to-mass) for individuals above the age of 20
c) Percentiles of *BMI* and estimated-adult *BMI* for individuals below the age of 20
d) Percentiles of *BMI* and statuses (pertaining-to-mass) for individuals below the age of 20

The percentile of *BMI* is to be determined from *BMI* tables for children. Other important concepts put forward were**:** (*iv*) replacement of height (growth) velocities and rates of gain/loss of mass by interpretation of height- and mass-percentile trajectories, (*v*) 'Status (pertaining-to-height)' — the ratio of absolute difference of height and current-age-mid-parental height to current-age-mid-parental height, expressed as percentage (*vi*) pseudo gain of height/mass, (*vii*) quantitative recommendations to gain height (*cm/month*) and gain/lose mass (*kg/month*) — KJA and KAJ Models, (*viii*) energy-channelization problem, which explained coexistence of wasting and tallness as well as obesity and stunting — KJR Model and (*viiii*) puberty-induced energy-channelization

KJ-Regression Model empowered KJA and KJR Models to replace upper and lower limits with actual values, when the relevant percentiles fell below 3 or rose above 97, thus, effectively, eliminating the need to establish methods to deal with extreme cases. Regression analysis gave very good results for data of height versus percentile as well as mass versus percentile. In future, there is a need to develop models of growth-and-obesity on the basis of regression curves, which do not require linear interpolation.

KJ, KJA, KAJ and KJ-Regression Models are robust. These models can be employed for data from any country or ethnicity. As soon as growth charts for the Pakistani population, developed through proper sampling techniques, preferably taking into account different somatotypes (Kamal *et al.*, 2004), on the basis of anthropometric measure-ents obtained following standardized protocols, are available, these charts may be incorporated in the software of these models, so that the models become realistic representations of health statuses of children of this country.

Future directions should include substantiation of KJA, KJR, KAJ and KJ-Regression Models in prospective follow-up studies and clinical trials to answer the questions**:**

- Do children and adolescents that follow the roadmap and reach their projected milestones do better, metabolically, than their peers? Who do not?
- What are there lipid profiles, blood pressures and glucose levels?
- Are weight and height milestones, equally, important? Alternatively, is their relevance to metabolic health limited, strictly, to *BMI* values, which, obviously, account for both parameters?

These and the other questions are likely to allow the future researcher, using the tools of anthromathematics (Kamal, 2010; Kamal *et al.*, 2014*c*) and anthrodynamics (Kamal and Jamil, 2013), to conclude whether recommendations made based on these models are expected to result in improved health consequences for children.

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ENDNOTES

[a]These examples first appeared in Additional file of (Kamal, 2014), where calculations were done using growth charts published in (Kamal and Jamil, 2012). In this paper, calculations are performed using extended charts given in Figures 9-12 as well as in Additional File 3.

[b]'The NGDS (National Growth and Developmental Standards for the Pakistani Children) Pilot Project' (http://ngds.uok.edu.pk) was initiated in 1998 as a community-based project on the directives of Governor Sindh/Chancellor, University of Karachi. Data are collected on over 3000 children in Army Public School, 'O' Levels, Saddar, Bahria College, NORE I, Beacon Light Academy, Gulshan-é-Iqbal, Fazaia (PAF) Degree College, Faisal, all of them located in Karachi, Pakistan.

[c]'Informed Consent Form' is uploaded at: http://www.ngds-ku.org/ngds_folder/Protocols/NGDS_form.pdf

[d]SGPP stands for 'Sibling Growth Pilot Project' (http://www.ngds-ku.org/ngds_URL/subprojects.htm#SGPP), in which parents and their children, 3-10-year old, visit SF-Growth-and-Imaging Laboratory for detailed checkup.

[e]'SGPP Participation Form' (http://www.ngds-ku.org/SGPP/SGPP_form.pdf) explained SGPP protocols and provided links to reading material and procedure-photographs.

[f]The growth tables and charts, reported in this work, are extensions of growth tables and charts, which were released by the Centers for Disease Control and Prevention (http://www.cdc.gov), Atlanta, Georgia, USA.

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