INT. J. BIOL. BIOTECH., **8 (1): 87-96, 2011**

GROWTH-AND-OBESITY PROFILES OF CHILDREN OF KARACHI USING BOX-INTERPOLATION METHOD

Syed Arif Kamal[1] *, Nida Jamil[2] and S. A. Khan[1 #]

[1]*SF Growth and-Imaging Laboratory, Department of Mathematics, University of Karachi, Pakistan*;
[2]*Department of Mathematics, Jinnah University for Women, Karachi, Pakistan;* [1]*e-mail*: profdrakamal@gmail.com

ABSTRACT

This paper introduces quantifiable growth-and-obesity profiles of children in family-centered care. This work presents a model based on the mathematical-statistical technique of 'box interpolation', which generates patient- and parent-friendly profiles based on one set of height and weight measurements of parents and children. Adult-mid-parental (Target) heights and optimal weights were compared with measured heights and weights to determine if the children were obese (wasted) and tall (stunted), associating a numerical index with each condition, in the form of percentage. This model, also, estimated adult-heights and weights of children and indicated whether parents were obese (wasted). Data were collected by authors, following standard protocols developed by our team, as part of the NGDS (National Growth and Developmental Standards) Pilot Project. This project was approved by 'Institutional Review Board'. Informed consents were obtained from parents of participating families. Each child was weighed and measured, in the presence of father and mother, barefoot, wearing short underpants, stripped to waist. Data from 70 participants of different localities of Karachi (17 families, consisting of 17 fathers, 17 mothers, 16 boys, 20 girls) were analyzed. Boys showed a greater risk of obesity (46.15%) as compared to girls (17.65%), when both parents were obese (15 families). Excessive obesity (wasting), failure-to-grow, short children developing normally, and failure-to-thrive, children neither growing nor developing normally, may be the cause of an underlying physical or psychological problem needing a head-to-toe evaluation. The method reported in this paper may be helpful in identifying such cases in children 3-10-year old, if regular height and weight screenings are conducted.

Keywords: Box interpolation, children, growth modeling, anthropometry, optimal weight, adult-mid-parental height

INTRODUCTION

Children are assets of any nation. The future of a country depends on strong and healthy children (Shen *et al.*, 1996). Parents, teachers and counselors are interested in knowing growth profile of children to plan better their exercise and diet programs. In particular, parents are keen to find out how their children are doing in terms of height and weight. They are, also, eager to learn what is going to be final height and final weight of their sons or daughters (Karlberg, 1996; Joss *et al.*, 1983; Hintz *et al.*, 1999; Rosenfeld 2003).

Obesity is becoming a problem worldwide among children and adolescents (Whittaker *et al.*, 1997; Ebbeling *et al.*, 2002). The incidence of childhood obesity has increased by more than 50 percent in the last decade (Siedentop, 2003), mainly because of a lack of physical activity (Christodoulos, 2006). It is related to a number of complications in adulthood (Reilly *et al.*, 2003). There is a conscious that the earlier the problem is detected, the more efficient and effective are the intervention strategies (Ludwig, 2007). However, in the absence of an objective, quantifiable criterion to determine severity of obesity, it becomes difficult to identify at risk cases and, hence, control the situation. The problem is compounded by a lack of awareness among the communities, absence of standardized equipments and standard operating procedures, inadequate training of the anthropometrists (sometimes non-professionals collect the data) and improper handing of data (researchers not trained in the statistical techniques).

We have investigated the prevalence of obesity in children, when both parents are obese, based on a growth-and-obesity profile, after developing a mathematical model and standardized protocols.

MODELS OF GROWTH

Correlation Model

Argyle *et al.* (2008) modeled and fitted the serial correlation structure of growth measurements of children. By this process, they achieved the benefit that monitoring growth at specific ages did not remain crucial, statistically.

ICP Model

The ICP (infancy-childhood-puberty) model is a time series, representing height of child (on *y* axis) as a function of age (on *x* axis) (Karlberg, 1987; 1996). Zero time is the moment of birth and zero height corresponds to

*PhD (Mathematical Neuroscience); MA, Johns Hopkins, Baltimore, MD, United States; Project Director, the NGDS Pilot Project; *paper mail***:** Professor and Head, Anthromathematics Group, Department of Mathe-matics, University of Karachi, Karachi 75270, Pakistan; *telephone***:** +92 21 9926 1300-15 ext. 2293; *homepage***:** http://www.ngds-ku.org/kamal; *project URL***:** http://ngds-ku.org

[#]MSc (Health and Physical Education)

conception, x intercept representing term of baby and y intercept birth length. During the phase transitions, infancy-to-childhood phase and childhood-to-puberty phase, the growth curve (height) is continuous, but not smooth. Therefore, height velocity is not defined during phase transitions.

KFA Model

The growth model developed by our group (Kamal *et al.*, 2004), referred to as KFA (Kamal-Firdous-Alam) model, assumed that the growth curves (height and mass graphs) were linear if the measurements were performed 6-*month* apart — a good approximation for most of the regions, except where there was a rapid change (during phase transitions; height velocity undefined) of growth rate. Other than these transition regions, height at some age grid, say, 6.0 or 6.5 *years*, was computed using linear interpolation. Boys' (B) and girls' (G) target (adult-mid-parental) heights (taken as reference), were computed using the biological father's (F) and the biological mother's (M) measured heights, respectively (Karllberg, 1996; Tanner *et al.*, 1970; Chianese, 2005).

(1*a*, *b*) $$B = \frac{F + M + 13}{2};\ G = \frac{F + M - 13}{2}$$

All heights were in *centimeters* (*cm*) and masses in *kilograms* (*kg*). Multiplying mass by a factor of 2.205 would generate weight in *pounds* (*lb*). These computed heights were extrapolated backwards to compute desired height at the reference-age grid. This was compared with the interpolated-actual height at the same age to determine whether the child was stunted (short-for-age) or tall. Body-mass index was computed by taking the ratio of mass (in *kg*) to square of height (in *meters*) and compared with the reference value to determine obesity profile. In addition, optimum mass for given height was determined and compared with the actual mass to find out whether the child was obese or wasted (lesser-mass-for-height). The model had provisions to compute height velocities and rates of gain/loss of weight, in order to predict height and weight during the next 6 *months*.

The KFA model required 2 sets of measurements separated by 6 *months* to generate a complete profile. While helpful for pediatricians, the time frame required in generating the first set of results (six and a half *months* after the original checkup) may put a severely wasted child at a great health risk.

METHODS

Project Protocols

The NGDS (National Growth and Developmental Standards for the Pakistani Children) Pilot Project Protocols were designed after taking into account of prevailing North American as well as European ethical and human-right standards (Kamal *et al.*, 2002) — 'Informed Consent Form' may be viewed at:

http://www.ngds-ku.org/ngds_folder/Protocols/NGDS_Form.pdf

The project was initiated after 'Institutional Review Process' by University of Karachi authorities, which included committees of Chancellor (Governor Sindh) and Vice Chancellor. SGPP (Sibling Growth Pilot Project) is a subproject of the NGDS Pilot Project, in which preteen children, father and mother of a given family are weighed and measured at SF-Growth-and-Imaging Laboratory. Informed consent was obtained by requiring both parents to sign 'SGPP Participation Form' http://www.ngds-ku.org/SGPP/SGPP_Form.pdf, which included address of web-site (http://ngds.uok.edu.pk) and contained detailed information and photographs of procedures. The families were given detailed written and verbal instructions to prepare children for the checkups and maintain standardization of procedures. Upon arrival, the families were briefed on procedures and their questions answered. All measurements were carried out in the morning hours (children are, generally, taller in the morning as compared to bedtime), with the children completely undressed except for briefs or panties, in the presence of father and mother. Acoustic, visual and data privacy of the participants was maintained. Parents were given the opportunity to discuss growth-and-obesity profile with the Project Director.

Laboratory Techniques

Heights, h, and masses, μ, were measured according to protocols developed by the NGDS Team (Kamal, 2006). These are, briefly, described here. For measurement of stature, the children were aligned to the mounted measuring tape and instructed to keep hands straight and open, palms touching thighs, holding breath. A pencil was held at eye level so that head is straight. Heights were recorded to nearest 0.1 *cm* by placing setsquares on the mounted engineering tape. Masses were recorded to nearest 0.1 *kg*, using a standard beam scale. Children were asked to step on the scale with empty hands, (anatomical position) holding breath, standing in the center and looking straight. At the start of each measurement session, a standard 100-*cm* ruler and a standard 2-*kg* mass were used to calibrate the height-measurement system and the beam scale, respectively (Kamal, 2009).

Table 1. Parents' Obesity Profiles

	Father	*Mother*
Case Number	**SGPP-KHI-20080104-02**	
Date of Birth	1970-01-13	1973-11-04
Date of Checkup	2009-02-05	2009-02-05
Age (*years*)	39.08	35.25
Height, *h* (*cm*)	169.3	154.9
Height (*ft-in*)	5 *ft* 6.65 *in*	5 *ft* 0.98 *in*
Percentile-of-Height, *P*(*h*)	16.00	10.53
Gross Mass (*kg*)	71.4	50.7
Clothing Correction (*kg*)	0.4	0.5
Net Mass, μ (*kg*)	71.0	50.2
Net Weight (*lb-oz*)	156 *lb* 8.88 *oz*	110 *lb* 11.06 *oz*
Percentile-of-Mass, $P(\mu)$	51.47	17.31
BMI, $10^4\mu/h^2$ (kg/m^2)	24.77	20.92
Optimal Mass (*kg*)	60.25	48.39*
Optimal Weight (*lb-oz*)	132 *lb* 13.62 *oz*	106 *lb* 11.20 *oz**
Δ Mass-for-Height	+ 10.75	+ 1.81*
Δ Weight-for-Height (*lb-oz*)	+ 23 *lb* 11.26 *oz*	+ 3 *lb* 15.82 *oz**
STATUS **(μ)**	**17.84% OBESE**	**3.74% OBESE***

* Valid if the mother is 'not pregnant'; in case of pregnancy add estimated weight of fetus and re-determine difference of mass (weight)-for-height and status

Mathematical Model

Growth-and-obesity profile of the family was determined by first converting dates of birth and dates of measurement (all dates recorded as *YYYY-MM-DD*: *year* in four digits-*month* in two digits-*day* in two digits) in decimal form and computing age as their difference (Appendix A gives the detailed procedure). For father (mother), height and mass percentiles of boy (girl) at the age 20 *years* were used to determine percentiles of measured height and mass, $P(h)$ and $P(\mu)$, respectively, by linear interpolation. For this purpose, percentiles in the growth table corresponding to lower and higher values 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} — the concept of optimal mass is being introduced in this paper to estimate status (pertaining-to-weight). If net mass, μ, was more (less) than the optimal mass, the person was considered as obese (wasted). Net mass (mass with zero clothing) was obtained by subtracting clothing correction from gross mass (mass in indoor clothes). Status (pertaining-to-mass) was expressed as a percentage

(2) $$STATUS\ (\mu) = 100\ \frac{|\mu - \mu_{\text{opt}}|}{\mu_{\text{opt}}}\ \%$$

1% variation from optimal mass (end points included) was considered normal (*cf.* Table 1). Equations (1) are used to compute adult-mid-parental (target) heights for boy and girl. Percentiles, corresponding to target heights (*cf.* Table 2), were obtained using procedures similar to those for obtaining percentiles corresponding to heights of father and mother. 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 (constant-percentile route; computations were done for 3 or 4 percentiles, to make sure that the required interval was not missed). Once the upper and the lower bounds were available at the given age, required percentile was determined by another linear inter-

Table 2. Adult-mid-parental (Target) heights

BOY/GIRL = (*FATHER* + *MOTHER* ± 13)/2	*BOY*	*GIRL*
Case Number	**SGPP-KHI-20080104-02**	
Adult-Mid-Parental (Target) Height (*cm*)	168.6	155.6
Adult-Mid-Parental (Target) Height (*ft-in*)	5 *ft* 6.38 *in*	5 *ft* 1.26 *in*
Percentile-of-Mid-Parental Height	13.67	13.00

Table 3. Growth-and-Obesity Profiles of children[@]

Child's Initials	*E. M.*	*L. M.*
Case Number	**SGPP-KHI-20080104-02**	
Photograph[©]		
Scanned Signatures[©]	EM	LM
Gender	Female	Female
Date of Birth	1999-12-05	2002-10-28
Birth Weight (*lb*)	6	7
Date of Checkup	2009-02-05	2009-02-05
Age (*years*)	9.17	6.27
Height, *h* (*cm*)	128.15	117.15
Height (*ft-in*)	4 *ft* 2.45 *in*	3 *ft* 10.12 *in*
Percentile-of-Height, *P*(*h*)	18.45	56.67
Estimated-Adult Height (*cm*)[§]	157.14	164.57
Estimated-Adult Height (*ft-in*)[§]	5 *ft* 1.87 *in*	5 *ft* 4.79 *in*
Mid-Parental-Height Percentile	13.00	13.00
Current-Age-Mid-Parental Height (*cm*)	126.88	110.47
Δ Height-for-Age (*cm*)	+ 1.27	+ 6.68
Δ Height-for-Age (*in*)	+ 0.50	+ 2.63
***STATUS* (*h*)**	**1.00% (+)[#]**	**6.04% TALL**
Gross Mass (*kg*)	18.9	17.2
Clothing Correction (*kg*)[¶]	0	0
Net Mass, μ (*kg*)	18.9	17.2
Net Weight (*lb-oz*)	41 *lb* 10.79 *oz*	37 *lb* 14.82 *oz*
Percentile-of-Mass, *P*(μ)	<3	6.87
Estimated-Adult Mass (*kg*)	<45.25	47.15
Estimated-Adult Weight (*lb-oz*)	<99 *lb* 12.42 *oz*	103 *lb* 15.58 *oz*
BMI, $10^4\mu/h^2$ (kg/m^2)	11.51	12.53
Optimal Mass (*kg*)	25.11	21.49
Optimal Weight (*lb-oz*)	55 *lb* 5.88 *oz*	47 *lb* 6.17 *oz*
Δ Mass-for-Height (*kg*)	– 6.21	– 4.29
Δ Weight-for-Height (*lb-oz*)	– 13 lb 11.06 oz	– 9 lb 7.30 oz
***STATUS* (μ)**	**24.73% WASTED**	**19.80% WASTED**

[@] Detailed Growth-and-Obesity Profiles and Calculations are uploaded as **Additional File 1 — Profiles of M. Family:** http://www.ngds-ku.org/Papers/J29/Additional_File_1.pdf and **Additional File 2 — Calculations of M. Family:** http://www.ngds-ku.org/Papers/J29/Additional_File_2.pdf, respectively.

[©] Photograph and scanned signatures on the day, check up was conducted. In order to protect the privacy of M. Family, the photographs, inserted in these Growth-and-Obesity Profiles, do not show the actual children, although they are from the set of patients, who reported to SF Growth-and-Imaging Laboratory for checkups. Further, family labels and children's initials do not correspond to first letters in actual names (as per confidentiality standards). Same is true about case numbers appearing in the main and the auxiliary documents. They are not the ones, which are used to classify patient record and appear on the reports issued to patients.

[§] Cutoff heights for induction in Armed Forces of Pakistan: Boy 5 *feet* 4 *inches* (162.56 *cm*); Girls 5 *feet* 2 *inches* (157.48 *cm*)

[¶] Clothing correction was taken as zero for both children. The girls were weighed and measured wearing panties only, barefoot and stripped to waist.

[#] (+) means the child has excess height as compared to current-age-mid-parental height, but is not considered tall.

polation (constant-age route). As soon as these percentiles were available, a qualitative judgment could be made (*cf*. Table 3). If the height percentile was lesser (greater) than the mass percentile, the child was considered as obese

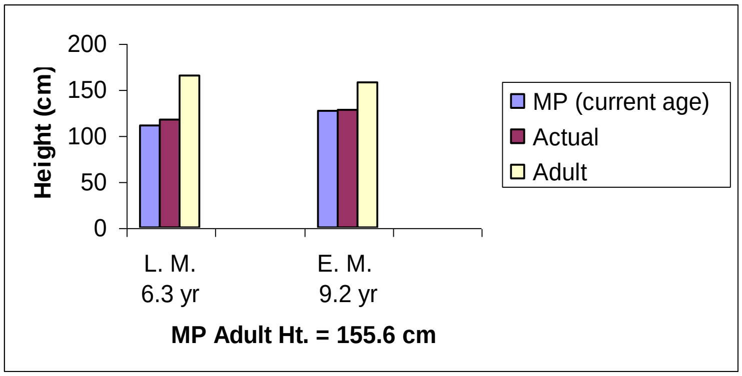

Fig. 1. Bar chart representing heights of girls

(wasted). Similarly, if the height percentile was greater (lesser) than the target-height percentile, the child was considered as tall (stunted). Optimal mass could be computed by 2 routes. First one was the constant-age route, which determined upper (lower) limit of optimal mass for later- (earlier-) age grid. From these limits, optimal mass was computed by linear interpolation (constant-percentile route). Second one was the constant-percentile route, which determined upper (lower) limit of optimal mass for higher (lower) percentile. From these limits, optimal mass was computed by linear interpolation (constant-age route). Both of these procedures gave identical results. Obesity profile was, then, determined using equation (2). 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 heights, $h_{\text{CA-MP}}$, would indicate if the child is tall (stunted). Status (pertaining-to-height) could be expressed as a percentage using**:**

(3) $$STATUS\,(h) = 100\ \frac{|h - h_{\text{CA-MP}}|}{h_{\text{CA-MP}}}\ \%$$

1% variation from current-age-mid-parental height (end points included) was considered normal. The above procedure was termed as 'Box Interpolation'. This procedure works well when the height and mass percentiles, both, lie between 3 and 97. Procedures for extreme cases are listed in Appendix B.

Sample Growth-and-Obesity Profile of M. Family (SGPP-KHI-20080104-02)

Estimated-adult heights and estimated-adult masses (weights) are based on percentiles of current height and mass, respectively. Parents' obesity profiles and adult-mid-parental (target) heights are listed in Tables 1 and 2, respectively. Table 3 lists growth-and-obesity profiles of children. Figures 1 and 2 consist of bar-chart representations of heights and masses (as mass of E M. lies below 3rd percentile, her adult mass could not be compu-

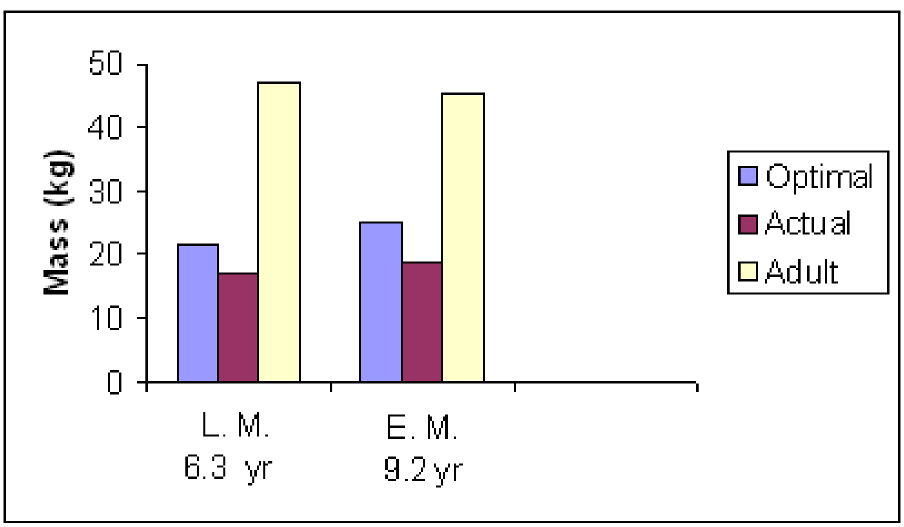

Fig. 2. Bar chart representing masses of girls, yellow bar for E. M. gives upper limit (her mass lies below 3rd *percentile*)

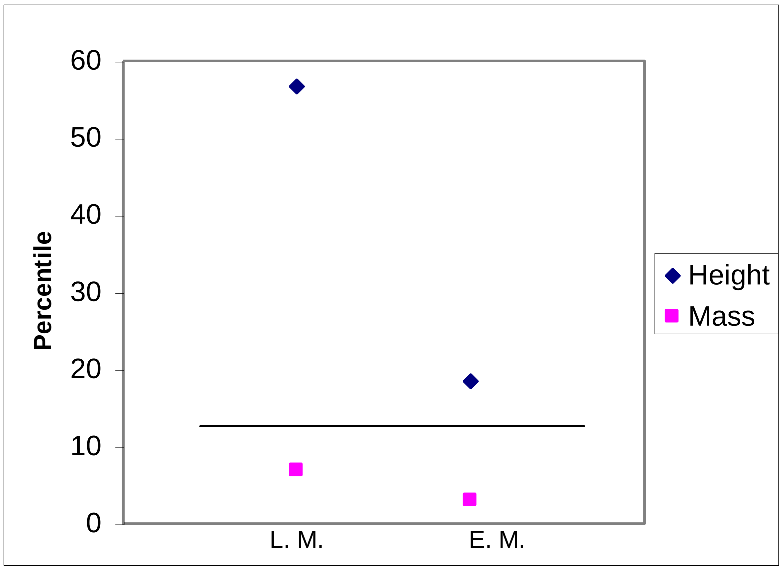

Fig. 3. Percentiles of heights and masses of girls; pink square for E. M. gives upper limit (her mass lies below 3rd *percentile*) — solid line gives mid-parental (reference) percentile

ted — the yellow bar represents upper limit only). Percentiles of height and mass are shown in Figure 3.

FATHER has 10.75 *kg* EXCESS mass (OVERWEIGHT by 23 *lb* 11.26 *oz*) for height [17.64% OBESE]. MOTHER has 1.81 *kg* EXCESS mass (OVERWEIGHT by 3 *lb* 15.82 *oz*) for height [3.74% OBESE], provided she is not pregnant (see note below Table 1). Since both children are girls, mid-parental percentile, 13th, is taken as reference.

*Height Profile (E. M.)***:** At the age of 9.17 *years*, (average) height of E. M. comes out to 128.15 *cm* (4 *ft* 2.43 *in*), which lies at 18th (18.45 to be exact) *percentile* [1.00% (+)]. E. M. has 1.27 *cm* (0.50 *in*) EXCESS height with respect to the mid-parental (reference) height at the current age, but is not considered tall. Based on this percentile, her estimated-adult height comes out to be 157.14 *cm* (5 *ft* 1.87 *in*).

*Mass Profile (E. M.)***:** At the age of 9.17 *years*, (average) net mass (weight) of E. M. comes out to 18.9 *kg* (41 *lb* 10.79 *oz*), which lies below 3rd *percentile* [24.73% WASTED]. E. M. has 6.21 *kg* LESSER mass (UNDERWEIGHT by 13 *lb* 11.06 *oz*) for her height. Based on this percentile, her estimated-adult mass (weight) comes out to be less than 45.25 *kg* (less than 99 *lb* 12.42 *oz*).

Height Profile (L. M.): At the age of 6.27 years, (average) height of L. M. comes out to 117.15 cm (3 *ft* 10.12 *in*), which lies at 57th (56.67 to be exact) *percentile* [6.04% TALL]. L. M. has 6.68 *cm* (2.63 *in*) EXCESS height with respect to the mid-parental (reference) height at the current age. Based on this percentile, her estimated-adult height comes out to be 164.57 *cm* (5 *ft* 4.79 *in*).

*Mass Profile (L. M.)***:** At the age of 6.27 *years*, (average) net mass (weight) of L. M. comes out to 17.2 *kg* (37 *lb* 14.82 *oz*), which lies at 7th (6.87 to be exact) *percentile* [19.80% WASTED]. L. M. has 4.29 *kg* LESSER mass (UNDERWEIGHT by 9 *lb* 7.30 *oz*) for her height. Based on this percentile, her estimated-adult mass (weight) comes out to be 47.15 *kg* (103 *lb* 15.58 *oz*).

Study Population and Parameters

Families from different localities of Karachi were invited to participate in the study. We studied those families in which children 3-10-year old were not suffering from any disease and both parents were willing to come to SF Growth-and-Imaging Laboratory for measurements. Results from 70 participants (17 fathers + 17 mothers + 16 boys + 20 girls) are presented. Based on the above mathematical model, a detailed growth-and-obesity profile of each family was generated and prevalence of obesity among children was studied keeping in view whether one or both parents are obese.

RESULTS

Out of 16 boys, 6 were found to be obese (both parents obese), 4 in the normal range (both parents obese) and 5 wasted (3 had both parents obese, 2 had wasted fathers and obese mothers). Obesity status for one boy could not be determined because his height and weight both fell below 3rd *percentile*. Out of 20 girls, 3 were found to be obese (both parents obese), 4 in the normal range (both parents obese) and 12 wasted (11 had both parents obese, 1 had normal father and wasted mother). Obesity status for one girl could not be determined because her height and weight both fell below 3rd *percentile*. Next, we considered prevalence of obesity in children of families, where both parents were obese. There were 15 such families. Out of a total of 13 such boys, 6 were obese (46.15%), 4 normal (30.77%) and 3 wasted (23.08%), whereas among 17 such girls, 3 were obese (17.65%), 4 normal (23.53%) and 10 wasted (58.82%). Hence, it appears that boys have a greater risk of obesity as compared to girls, when both parents were obese. Girls, in these families, on the other hand, are showing a tendency of being underweight — a common phenomenon in developing countries undergoing the nutrition transition (Armstrong *et al.*, 2003; Caballero, 2005; Jinabhai *et al.*, 2003).

DISCUSSION

Childhood obesity is associated with a number of adverse consequences (Dietz and Robinson, 2005). Even a very small amount of increase in weight is going to elevate the risk factor of coronary heart disease in adulthood (Baker *et al.*, 2007; Bibbins-Domingo *et al.*, 2007). Obesity, combined with inactivity, has been linked to diabetes (Rocchini, 2002; Sinha *et al.*, 2002) and cancer (Roizen and Oz, 2005). Many obese children have low levels of spontaneous activity (Brukner and Khan, 2002). Degree of obesity, expressed as percentage in our method, has many clinical implica-tions in children and adolescents (Weiss *et al.*, 2004; Jolliffe, 2004). An obese child with Blount's disease faces significant morbidity (Campbell *et al.*, 2006). Similarly, obesity is a common problem occurring in children with myelomeningocele that can affect independence and proficiency with transfers, mobility and self-care activities (Campbell *et al.*, 2006).

The methods, presented in this paper, generate results in a format easily understandable by parents and older children, avoiding technical jargon. In addition to the descriptive format, the information is presented in bar chart form (for giving a general perspective to families) and tabular form (for quick review by the attending pediatrician). This growth-and-obesity profile may prove valuable for pediatricians, nutritionists (Nestle, 2006) and physical education teachers (Siedentop, 2003), who may, together, plan diet-cum-exercise programs (Seth and Shah, 2006), supplemented by medicines, if required. In addition, parental obesity profile may be taken as a guideline to initiate family-centered-optimum-weight-for-height programs. There is a dire need to accurately monitor growth and development of a child (Freedman *et al.*, 2004; Barker *et al.*, 2005; Lawlor *et al.*, 2006). *Failure-to-Grow* (Harris *et al.*, 2001) is the first indictor of an underlying physical problem, requiring a complete examination by a pediatrician. *Failure-to-Thrive* may signal a much deeper problem, psychosomatic in origin, which must be taken seriously requiring a head-to-toe (stripped totally) examination as well as a psychiatric evaluation of the child to rule out neglect, emotional, physical or sexual abuse. According to Adam, "growth hormone is necessary, but not sufficient for a successful childhood" (Chianese, 2005). The authors recommend nationwide programs (Sultz and Young, 2004) to monitor height and weight of 3-10-year-old children, with improved techniques for measurement of height and weight (height and weight can now be measured to accuracies of 0.01 *cm* and 0.01 *kg*, respectively — Kamal, 2010), combined with a comprehensive approach to manage pediatric obesity (Miller and Silverstein, 2007), to ensure a happy, a healthy and an emotionally balanced adulthood, resulting in increase in life expectancy (Olshansky *et al.*, 2005).

ACKNOWLEDGEMENTS

The authors would like to thank Prof. Dr. Pirzada Q. R. Siddiqui, Vice Chancellor, for his patronage and constant appreciation of the group's work, Prof. Dr. Shahana Urooj Kazmi and Prof. Dr. Nasiruddin Khan, Pro-Vice Chancellors, for their encouragement, Prof. Dr. Darakhshan Jabeen Haleem, Dean, Faculty of Science, for financial assistance in the form of Dean's Research Grant, Prof. Dr. Sarwar Jahan Abbasi, Chairwoman, Department of Mathematics, University of Karachi for providing infrastructure, Prof. Dr. Duré-Samin Akram, Diplomat, American Boards in Pediatrics and Ex-President, Pakistan Pediatric Association for help in clinical aspects and Munir Hussain for IT support. (Late) Syed Firdous's assistance in conversion of growth charts to growth tables is, gratefully, acknowledged. No potential conflict of interest is identified for this work.

APPENDIX A: DATES IN FRACTIONAL FORM

Dates in the format *YYYY–MM–DD* may be converted to decimal form using the formulae

$$Y+\frac{Days(MM-1)+Days(DD)}{365}\text{ (non-leap year); }Y+\frac{Days(MM-1)+Days(DD)}{366}\text{ (leap year)}$$

Table 4. Cumulative days in a year

#	*Months*	**Non-leap Year**		**Leap Year**	
		Days	*Cumulative Days*	*Days*	*Cumulative Days*
01	January	31	31	31	31
02	February	28	59	29	60
03	March	31	90	31	91
04	April	30	120	30	121
05	May	31	151	31	152
06	June	30	181	30	182
07	July	31	212	31	213
08	August	31	243	31	244
09	September	30	273	30	274
10	October	31	304	31	305
11	November	30	334	30	335
12	December	31	365	31	366

and the data in Table 4.

APPENDIX B: EXTREME CASES (PERTANING TO OPTIMAL WEIGHT-FOR-HEIGHT)

If any one or both percentiles of height and mass, $P(h)$ and $P(\mu)$, lie outside the range [3, 97], the procedure for status computation is different from the one reported (*cf.* Table 5).

a) $P(h) < 3,\ P(\mu) \geq 3,\ \text{STATUS} > \dfrac{100(\mu - \mu_{3-\text{p}})}{\mu_{3-\text{p}}}$% OBESE, $\mu_{3-\text{p}}$ = 54.5 *kg* (for males), 45.25 *kg* (for females) and gender-specific-age-based mass corresponding to 3rd percentile computed from growth charts (for children), examples are worked out after discussion of case *d)* [valid even if $P(\mu) > 97$].

b) $P(\mu) > 97,\ 3 \leq P(h) \leq 97,\ \text{STATUS} = \dfrac{100(\mu - \mu_{\text{opt}})}{\mu_{\text{opt}}}$% OBESE. If $P(h) < 3$, use the formula given in (*a*).

c) $P(\mu) < 3,\ 3 \leq P(h) \leq 97,\ \text{STATUS} = \dfrac{100(\mu_{\text{opt}} - \mu)}{\mu_{\text{opt}}}$% WASTED.

d) $P(\mu) \leq 97,\ P(h) > 97,\ \text{STATUS} > \dfrac{100(\mu_{97-\text{p}} - \mu)}{\mu_{97-\text{p}}}$% WASTED, $\mu_{97-\text{p}}$ = 101.0 *kg* (for males), 88.75 *kg* (for females) and gender-specific-age-based mass corresponding to 97th *percentile* computed from growth charts (for children), examples are worked out below [valid even if $P(\mu) < 3$]. This result can be easily proved by writing the status formula as $100(1 - \dfrac{\mu}{\mu_{\text{opt}}})$ and use >101.0 *kg* (>88.75 *kg*), in place of μ_{opt}.

Gender-Specific-Age-Based Masses

Gender-specific-age-based masses corresponding to 3rd and 97th *percentiles* were evaluated using the following recipe**:**

Table 5. Extreme Cases

$P(h)$	$P(\mu)$	*Case* (*as referred below*)
< 3	< 3	Status non-determinable
< 3	$3 \leq P(\mu) \leq 97$	(*a*)
< 3	> 97	(*a*)
$3 \leq P(h) \leq 97$	< 3	(*c*)
$3 \leq P(h) \leq 97$	$3 \leq P(\mu) \leq 97$	Regular calculations
$3 \leq P(h) \leq 97$	> 97	(*b*), Regular calculations
> 97	< 3	(*d*)
> 97	$3 \leq P(\mu) \leq 97$	(*d*)
> 97	> 97	Status non-determinable

a) Corresponding to 3rd Percentile

Let us compute this parameter for the girl E. M. (SGPP-KHI-20080104-02/01), whose growth-and-obesity profile is given in Table 3. Her age is 9.17 *years*. From the table of masses for girls, read off the masses corresponding to 3rd percentile at ages 9.0 *years* and 9.5 *years*, as 21.5 *kg* and 22.5 *kg*, respectively. Using the equation of straight line (2-point form), with age, as independent variable, and mass, as dependent variable, $\mu_{3-\text{p}}$ (9.17 *years*) comes out to 21.84 *kg*. Similar calculations for a boy, T. J. (SGPP-KHI-20060412-01/04), age 5.82 *years*, require that one reads of the masses corresponding to 3rd percentile at ages 5.5 *years* and 6.0 *years*, as 16.0 *kg* and 16.5 *kg* and applies linear interpolation to obtain $\mu_{3-\text{p}}$ (5.82 *years*) as 16.32 *kg*.

b) Corresponding to 97th Percentile

Let us compute this parameter for the girl Q. J. (SGPP-KHI-20060412-01/02). Her age is 9.53 *years*. From the table of masses for girls, read off the masses corresponding to 97th percentile at ages 9.5 *years* and 10.0 *years*, as 47.25 *kg* and 51.0 *kg*, respectively. Using the equation of straight line (2-point form), with age, as independent variable, and mass, as dependent variable, $\mu_{97-\text{p}}$ (9.53 *years*) comes out to 47.475 *kg*. Similar calculations for a boy, L. T. Y. S. ((SGPP-KHI-20010105-01/01), age 7.91 *years*, require that one reads off the masses corresponding to 97th percentile at ages 7.5 *years* and 8.0 *years*, as 34.5 *kg* and 37.0 *kg* and applies linear interpolation to obtain $\mu_{97-\text{p}}$ (7.91 *years*) as 36.55 *kg*.

REFERENCES

Argyle, J., A. H. Seheult and D. A. Wooff (2008). Correlation models for monitoring child growth. *Statistics in Medicine*, 27 (6)**:** 888-904

Armstrong, J., A. R. Dorosty and J. J. Reilly (2003). Coexistence of social inequalities in under nutrition and obesity in preschool children. *Archives of Diseases of Children*, 88 (8)**:** 671-675

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 (23)**:** 2329-2337

Barker, D. J. P., C. Osmond, T. J. Forsén, E. Kajantie and J. G. Eriksson (2005). Trajectories of growth among children who have coronary events as adults. *New England Journal of Medicine*, 353 (7014)**:** 1802-1809

Brukner, P. and K. Khan (2002). *Clinical Sports Medicine*. Revised 2nd ed. McGraw Hill: Sydney, Australia, 671

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 (23)**:** 2371-2379

Caballero, B. (2005). A nutrition paradox — Underweight and obesity in developing countries. *New England Journal of Medicine*, 352 (15)**:** 1514-1516

Campbell, S. K., D. W. V. Linden and R. J. Palisano (2006). *Physical Therapy for Children*. 3rd ed. Saunders Elsevier**:** St. Louis, Missouri, United States, pp. 491, 754

Chianese, J. (2005). Short stature. *Pediatrics in Review*, 26 (1)**:** 36-37 — includes comment by Adam HM (editor, In Brief)

Christodoulos, A. D. (2006). Obesity and physical fitness of pre-adolescent children during the academic year and the summer period**:** Effects organized physical activity. *Journal of Child Health Care*, 10 (3)**:** 199-212

Dietz, W. H. and T. N. Robinson (2005). Overweight children and adolescents. *New England Journal of Medicine*, 352 (20)**:** 2100-2109 — D. S. Ludwig and C. B. Ebbeling; D. Kerr; W. H. Dietz and T. N. Robinson (2005). Overweight children and adolescents. *New England Journal of Medicine*, 353 (10)**:** 1070-1071 (correspondence)

Ebbeling, C. B., D. B. Pawlak and D. S. Ludwig (2002). Childhood obesity**:** Public-health crisis, common-sense cure. *Lancet*, 360 (9331)**:** 473-482

Freedman, D. S., L. K. Khan, M. K. Serdula, W. H. Dietz, S. R. Srinivasan and G. S. Berenson (2004). Inter-relationships among childhood *BMI*, childhood height and adult obesity**:** The Bogalusa Heart Study. *International Journal of Obesity*, 28 (1)**:** 10-16

Harris, N. S., P. B. Crawford, Y. Yangzom, L. Pinzo, P. Gyalsten and M. Hudes (2001). Nutritional and health status of Tibetan children living at high altitudes. *New England Journal of Medicine*, 344 (5)**:** 341-347

Hintz, R. L., K. M. Attie, J. Baptista and A. Roche (1999). Effect of growth hormone treatment on adult height of children with idiopathic short stature. *New England Journal of Medicine*, 340 (7)**:** 502-507

Jinabhai, C. C., M. Taylor and K. R. Sullivan (2003). Implications of the prevalence of stunting, overweight and obesity amongst South African primary school children: a possible nutritional transition? *European Journal of Clinical Nutrition*, 57 (2)**:** 358-365

Jolliffe, D. (2004). Extent of overweight among US children and adolescents from 1971 to 2000. *International Journal of Obesity*, 28 (1)**:** 4-9

Joss, E., K. Zuppinger, H. P. Shwartz and H. Roten (1983). Final height of patients with pituitary growth failure and changes in growth variables after long-term hormonal therapy. *Pediatric Research*, 17 (8)**:** 676-679

Kamal, S. A. (2006, May 23). Manual for obtaining anthropometric measurements. *The-NGDS-Pilot-Project-e-Publication*, University of Karachi, Karachi, Pakistan; full text**:** http://www.ngds-ku.org/ngds_folder/M02.pdf

Kamal, S. A. (2009, December 16, 17). Mathematics of experimentation, *National Conference on Physics and the World of Today*, in memory of Prof. Dr. Muhammed Rafi and Prof. Dr. Muhammed Razi Hussain, Department of Physics, University of Karachi, Karachi, Pakistan, abstract#1, pp. 9, 10 (Prof. Dr. Muhammed Rafi and Prof. Dr. Muhammed Razi Hussain memorial lecture), abstract**:** http://www.ngds-ku.org/Presentations/Physics2.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, abstract#10, p. 19 (the Syed Firdous memorial lecture), abstract**:** http://www.ngds-ku.org/Presentations/Firdous.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 (4)**:** 707-717, full text**:** http://www.ngds-ku.org/Papers/J26.pdf

Kamal, S. A., S. J. Alam and S. Firdous (2002, June 22). The NGDS Pilot Project: 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

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*, 85 (417)**:** 61-63

Lawlor, D. A., R. M. Martin, D. Gunnell, *et al.* (2006). Association of body-mass index measured in childhood, adolescence and young adulthood with risk of ischemic heart disease and stroke: findings from 3 historical cohort studies. *American Journal of Clinical Nutrition*, 83 (4)**:** 767-773

Ludwig, D. S. (2007). Childhood obesity — The shape of things to come. *New England Journal of Medicine*, 357 (23)**:** 2325-2327

Miller, J. L. and J. H. Silverstein (2007). Management approaches for pediatric obesity. *Nature Clinical Practice in Endocrinology and Metabolism*, 3 (12)**:** 810-818

Nestle, M. (2006). Food marketing and childhood obesity — A matter of policy. *New England Journal of Medicine*, 354 (24)**:** 2527-2529

Olshansky, S. J., D. J. Passaro, R. C. Hershow, *et al.* (2005). A potential decline in life expectancy in the United States in the 21st century. *New England Journal of Medicine*, 352 (11)**:** 1138-1145

Reilly, J. J., E. Methven, Z. C. McDowell, *et al.* (2003). Health consequences of obesity. *Archives of Diseases of Children*, 88 (9)**:** 748-752

Rocchini, A. P. (2002). Childhood obesity and a diabetes epidemic. *New England Journal of Medicine*, 346 (11)**:** 854-855

Roizen, M. F. and M. C. Oz (2005). *You***:** *the Owner's Manual*.1st ed. HarperCollins**:** New York, United States, p. 334

Rosenfeld, R. G. (2003). Insulin-like growth factors and the basis of growth. *New England Journal of Medicine*, 349 (23)**:** 2184-2186

Seth, M. and N. Shah (2006). *The Scientific Way to Managing Obesity*. Sterling**:** New Delhi, India, pp. 64-67

Shen, T., J. P. Habicht and Y. Chang (1996). Effects of economic reforms on child growth in urban and rural areas of China. *New England Journal of Medicine*, 335 (6)**:** 400-406

Siedentop, D. (2003). *Introduction to Physical Education*, *Fitness and Sport*. 5th ed. McGraw Hill**:** Boston, Massachusetts, United States, pp. 18, 171

Sinha, R., G. Fisch, B. Teague, *et al.* (2002). Prevalence of impaired glucose tolerance among children and adolescents with marked obesity. *New England Journal of Medicine*, 346 (11)**:** 802-810

Sultz, H. A. and K. M. Young (2004). *Health Care USA*. 4th ed. Jones and Bartlett**:** Sudbury, Massachusetts, United States, p. 375

Weiss, R., J. Dziura, T. S. Burgert, *et al.* (2004). Obesity and the metabolic syndrome in children and adolescents. *New England Journal of Medicine*, 350 (23)**:** 2362-2374

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

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

(*Accepted for Publication***:** *December 2010*)

ADDITIONAL NOTE (*related to this paper, but not part of the published manuscript*)**:** Practice data are uploaded at**:** http://www.ngds-ku.org/Papers/J29/Additional_File_3.pdf. Although target (adult-mid-parental) heights for a boy and a girl are computed using different formulae, percentiles match sometimes because tables are different for males and females. Illustration of ICP model described on pp. 87, 88 is available at**:**

http://www.ngds-ku.org/Papers/J29/Additional_File_4.pdf

*Web address of this document (first author's homepage)***:** http://www.ngds-ku.org/Papers/J29.pdf
*Abstract***:** http://www.ngds-ku.org/pub/jourabstA.htm#J29: