

AN INVESTIGATION OF GROWTH PROFILES OF THE PAKISTANI CHILDREN

S. A. Kamal*, S. Firdous¹ and S. J. Alam²

Department of Mathematics, University of Karachi, Karachi, Pakistan; e-mail: profdrakamal@gmail.com

¹Department of Mathematics, S. M. Government Science College, Karachi, Pakistan

²Max-Planck-Institut für Informatik, Saarbrücken, Germany

ABSTRACT

The NGDS (National Growth and Developmental Standards for the Pakistani Children) Pilot Project was initiated in 1998 to establish Pakistan-based anthropometrical data library and growth charts, to formulate mathematical models, which predict growth parameters, to write softwares, which generate detailed growth profiles and to develop inexpensive anthropometry instruments from local resources, which could be employed in obtaining anthropometric measurements of the Pakistani rural and slum-area children. Standing and sitting heights, shoulder widths, weights and mid-upper-arm circumferences are measured on over 2000 healthy children. Mathematical procedure/software was developed, which takes as input heights and weights of biological parents, and those of child at 2 successive occasions, 6 months apart. The output is a detailed growth profile indicating stunting and wasting (if present), overweight/underweight conditions, height velocity, rate of weight gain/loss and body-mass index (comparison of all three with references). Failure-to-grow may be the first indication of a major underlying problem. The authors recommend growth monitoring and analysis of all 3-10-year-old children using this software.

Keywords: Anthropometry, Pakistani children, height, weight, growth velocity, stunting, nutritional assessment

INTRODUCTION

Anthropometry (measurement of the man) is one of the oldest sciences. To be able to use growth data fruitfully, there is a need to study and to constantly update growth charts (Karlberg *et al.*, 1999). They are used in the fields of health-care planning, education, industry and government (Hensinger, 1998). The techniques and the instrumentation must also be under constant scrutiny (Kamal, 1982; 1986; Kamal *et al.*, 1980). Literature is available on growth studies in North America (Rosner *et al.*, 1998), Europe (Edlund *et al.*, 1999; Moilanen and Rantakallio, 1989; Power *et al.*, 1997), Asia (Abolfotouh *et al.*, 1993; Ayatollahi, 1993) and Australia (Magarey *et al.*, 1999). There has not been a serious effort to develop growth standards for the Pakistani children. American and European growth standards are inadequate for Asian children. Approximation methods need to be devised to use them locally (Abolfotouh *et al.*, 1993). Inadequate furniture in schools, offices and public transport is an indication of lack of national standards. A study was started in 1998 to collect data on children, representing a national sample, in a better-than-average health (Kamal and Firdous, 2002a). This study was designed after taking into account complexities of the system and the operations (Kamal *et al.*, 2002e). The study sample consisted of 3-10-year-old-healthy boys and girls, studying in pre-primary and primary sections, *i. e.*, students in classes of ECE (Early Childhood Education) /Montessori as well as classes 1-5, having no complications before birth and during the weaning period. The sample, drawn from institutions run by the Armed Forces of Pakistan, represented all provinces and localities. In general, the children were healthier as compared to the average population. These children represented all socio-economic groups. Consent was obtained from parents employing opt-in policy through 'Informed Consent Form' http://www.ngds-ku.org/ngds_folder/Protocols/NGDS_Form.pdf — consent-form slips requested data regarding education and occupation of both parents as well as size of the nuclear family. This sample appeared to be ideal for establishing National Growth and Developmental Standards (NGDS) for the Pakistani Children. The growth profile was analyzed keeping in view the ICP model of growth (Karlberg 1987; 1996). The Early Childhood Integrated Developmental Examination, which covers the age range 3 to 8 years, was administered to selected children (Kamal 2002).

MATERIALS AND METHODS

Project Protocols

Barefoot standing heights, sitting heights, masses (weights), mid-upper-arm circumferences and shoulder widths were measured with the children undressed to short underpants, all clothing above the waist removed. Clothing left on the child as well as behavior exhibited during the measurement was recorded. Mathematical Codes, *i. e.*, Dress

*Syed Arif Kamal; PhD (Mathematical Neuroscience); MA, Johns Hopkins, Baltimore, MD, United States; Project Director, the NGDS Pilot Project; Sessional Faculty, the Aga Khan University Medical College, Karachi; *paper mail:* Professor and Chairman, Department of Mathematics, 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>

Code and Behavior Code were devised for this purpose. Children were measured during the morning hours, on the school premises (children are generally 1-1.5 *cm* taller in the morning as compared to bedtime). An engineering tape mounted on the wall was utilized. Standing height was recorded to the nearest millimeter with the child's back touching the tape, feet together, heels touching the wall, in anatomical position. Child was asked to breathe in and hold breath. A setsquare was used to read off heights. A similar procedure was adopted for recording sitting height. Mid-upper-arm circumference (MUAC) was taken on both arms and compared. Shoulder width was measured after asking the child to stand touching a wall and by placing setsquare on the free arm to record width. Mass (weight) was recorded, with the child instructed to breathe in, hold breath, and look at a pen held at the eye level (Kamal and Firdous, 2002a, b).

Children were screened for factors, which may contribute to growth retardation. These include screening for anemia, cardiac disease and spinal curvatures, specially, scoliosis. The tests used to detect spinal curvatures were: visual inspection of back in the anatomical and the mild-stretching positions, Adam's forward bending test and moiré fringe topography (Kamal, 1998). A certain routine was devised and followed for the check up (Kamal *et al.*, 2002c), taking into account influences of different tests on results of each other (Kamal *et al.*, 2002e).

Mathematical Model

It was assumed that the growth curves (height and weight graphs) were linear if the measurements were performed 6-month apart. This was a good approximation for most of the regions, except where there was 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 according to ICP model (Karlberg, 1987). Therefore, height velocity was not defined during phase transitions. Other than these transition regions, 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 following relations:

$$(1, 2) \quad B = \frac{F + M + 13}{2}, \quad G = \frac{F + M - 13}{2}$$

The variables, *B*, *G*, *F* and *M* represent boy's target height, girl's target height, biological father's measured height and biological mother's measured height, respectively. All heights were measured in centimeters.

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 height-for-age) or tall for age. Similar calculations were done for weight to determine if the child was overweight, normal or underweight for age. Body-mass index was computed by taking the ratio of mass (in *kilogram*) to square of height (in *meter*) and compared with the reference value to determine obesity profile. In addition, optimal mass for given height was determined and compared with the actual mass to find out whether the child was fat, normal or wasted (lesser mass-for-height). The model has provisions to compute height velocities and rates of gain/loss of weight, in order to predict height and weight during the next 6 *months*.

Software Development

Software was developed using Microsoft Visual Studio, Version 6.0 (Kamal *et al.*, 2002d). It has the following basic modules:

a) The child's database, *i. e.*, the software is able to create, to edit, to update and to query the record necessary for computation of growth profile. The module is a complete database by itself and necessary data modeling is done with requirement analysis.

b) A mathematical library for the software. All mathematical models, simple and complex, were coded in visual basic after being properly specified as programmable algorithms and the software computations would use this library, accordingly.

c) Output, in terms of graphical and numerical representations. Reports are generated and the necessary material is printable. This requires mathematical and graphics-based routines along with proper handling of plots.

d) A tutorial as an interactive guide for the users, which acts as reference.

The algorithm first identifies child's identity and retrieves record from its archives consisting of parents' height and child's previous measurements. If this is the first examination, the program creates a new record. Results can, only, be generated when data for at least 2 examinations are entered. Subroutines were written, which performed linear interpolations. Once the child's data are available the program reads reference heights and masses from the reference database to determine rates. There is another subroutine, which compares the reference values with the actual values and interprets the difference.

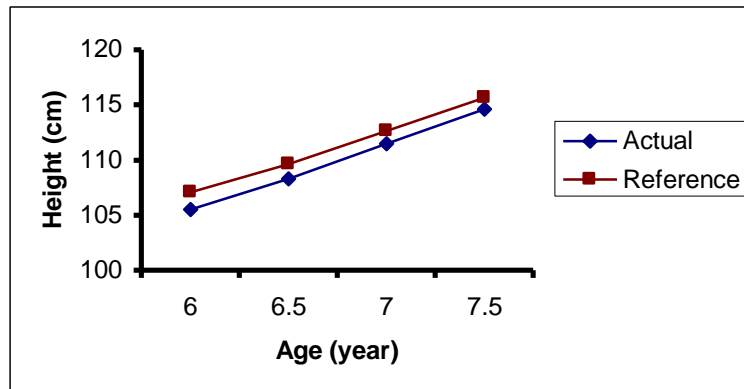


Fig. 1. Height profile in graphical form

RESULTS

Figures 1 and 2 show height profile in graphical and bar-chart forms. Table 1 lists growth parameters interpolated at the reference ages. Below are the measurements obtained during four check ups:

Vital Statistics (all dates given in the format: *year-month-day*) — child's initials do not correspond to first letters in her name (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. However, the authors can, immediately, track the actual case from the coded numbers included in this document.

Name: Z. R. Record Number: SGPP-KHI-19980228-01 (APS)
 Date of Birth: 1994-07-27 Gender: Female

Parents' Heights

Mother (measured): 150.8 cm on 2000-10-25 Father (reported): 5 feet 6 inches

Table 1. Actual growth parameters (interpolated at the reference ages)

Age	6 years	6 years 6 months	7 years 6 months
Height (cm)	105.5	108.3	114.6
Height (feet-inches)	3 feet 5.5 inches	3 feet 6.6 inches	3 feet 9.1 inches
Percentile-of-height	3.5	< 3	3.2
Mass (kg)	17.54	20.80	21.58
Weight (lb)	38.67	45.85	47.5
Percentile-of-weight	4.9	10.2	22.6

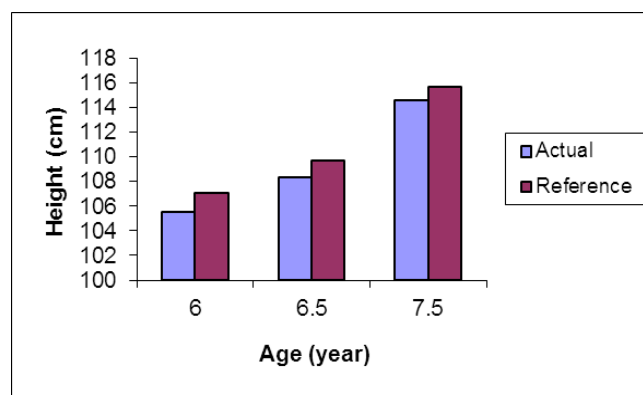


Fig. 2. Height profile in bar-chart form

History (provided by mother)

Hospitalization: Between her second and her third check-up Z. R. was hospitalized. Mother reported weight loss.

Physical Examination

Nutritional: Z. R. showed signs of anemia during her first three check ups. Mother was asked to have Blood Hemoglobin done. Her condition considerably improved during the fourth check up.

Cardiac: Z. R. had normal heart sounds (standing and squatting).

Trunk Deformities: Z. R. showed signs of trunk deformity during all her check ups. Mother was asked to have AP-X ray (standing) of the entire spine (external auditory meatus to hip joint), for the detection of scoliosis, done.

Anthropometry

First checkup on 1999-03-01	<i>Height:</i> 96.0 <i>cm</i> (child relaxed and coöperative) <i>Mass:</i> 13.5 <i>kg</i> (parents refer to his parameter as 'weight')
Second checkup on 2000-10-25	<i>Height:</i> 107.2 <i>cm</i> (child relaxed and coöperative) <i>Mass:</i> 17.0 <i>kg</i>
Third checkup on 2001-03-19	<i>Height:</i> 109.0 <i>cm</i> (child relaxed and coöperative) <i>Mass:</i> 19.0 <i>kg</i>
Fourth checkup on 2002-04-06	<i>Height:</i> 115.9 <i>cm</i> (child relaxed and coöperative) <i>Mass:</i> 21.0 <i>kg</i>

Growth Profile

Adult-MP (Target) height: 152.72 *cm* (5 feet 0.13 *inch*) [MP stands for 'mid-parental']
Adult-MP mass (weight): 46.67 *kg* (102.91 *lb*) [corresponding to adult-MP height]
CDC-growth-curve percentile: 5.489 [corresponding to MP height]

Between the First and the Second Checkup

Height-for-age profile: 1.57 *cm* (0.62 *inch*) SHORT for age [STUNTED]
Height-velocity-for-age profile: Height velocity 0.23 *cm/year* (0.09 *inch/year*) MORE than the reference value [growing FAST]
Height prediction: 108.9 *cm* (3 feet 6.9 *inches*) at 6 years 6 months
Mass-for-age 0.07 *kg* LESSER mass for age
(Weight-for-age) profile: (UNDERWEIGHT for age by 0.16 *lb*)
Rate-of-mass-gain-for-age 0.08 *kg/year* (0.17 *lb/year*) LESSER than the reference value
(weight-gain-for-age) profile: [rate LOW]
Mass (Weight) prediction: 17.54 *kg* (38.67 *lb*) at 6 years 6 months
Obesity profile: Body-mass index (*BMI*) 0.31 *kg/m²* MORE than the reference value [OBESE]
Mass-for-height 0.35 *kg* EXCESS mass for height (OVERWEIGHT for height by 0.76 *lb*)
(Weight-for-height) profile: [FAT]

Between the Second and the Third Checkup

Height-for-age profile: 1.35 *cm* (0.53 *inch*) SHORT for age [STUNTED]
Height-velocity-for-age profile: Height velocity 1.53 *cm/year* (0.60 *inch/year*) LESSER than the reference value [growing SLOW]
Height prediction: 110.6 *cm* (3 feet 7.5 *inches*) at 7 years
Mass-for-age 0.93 *kg* EXCESS mass for age
(Weight-for-age) profile: (OVERWEIGHT for age by 2.04 *lb*)
Rate-of-mass-gain-for-age 3.27 *kg/year* (7.20 *lb/year*) MORE than the reference value
(weight-gain-for-age) profile: [rate HIGH]
Mass (Weight) prediction: 20.80 *kg* (45.85 *lb*) at 7 years
Obesity profile: Body-mass index (*BMI*) 1.61 *kg/m²* MORE than the reference value [OBESE]

Table 2. Growth profile

Δ (Growth Parameter) = Reference Value – Actual Value	Between 1 st and 2 nd Checkup	Between 2 nd and 3 rd Checkup	Between 3 rd and 4 th Checkup
Δ Height-for-age (cm)	-1.57	-1.35	-1.06
Δ Height-for-age (inch)	-0.62	-0.53	-0.41
Status	STUNTED	STUNTED	STUNTED
Δ Height-velocity-for-age (cm/year)	+0.23	-1.53	+1.03
Δ Height-velocity-for-age (inch/year)	+0.09	-0.60	+0.40
Status	Growing FAST	Growing SLOW	Growing FAST
Δ Mass-for-age (kg)	-0.07	+0.93	+1.53
Δ Weight-for-age (lb)	-0.16	+2.04	+3.38
Status	UNDERWEIGHT	OVERWEIGHT	OVERWEIGHT
Δ Rate-of-mass-gain-for-age (kg/year)	-0.08	+3.27	+0.13
Δ Rate-of-weight-gain-for-age (lb/year)	-0.17	+7.20	+0.29
Status	Rates LOW	Rates HIGH	Rates HIGH
Δ Body-mass index (kg/m ²)	+0.31	+1.61	+1.57
Status	OBESE	OBESE	OBESE
Δ Mass-for-height (kg)	+0.35	+1.89	+2.07
Δ Weight-for-height (lb)	+0.76	+4.17	+4.56
Status	FAT	FAT	FAT

Mass-for-height 1.89 kg EXCESS mass for height.
(Weight-for-height) profile: (OVERWEIGHT for height by 4.17 lb) [FAT]

Between the Third and the Fourth Checkup

Height-for-age profile: 1.06 cm (0.41 inch) SHORT for age [STUNTED]
Height-velocity-for-age profile: Height velocity 1.03 cm/year (0.40 inch/year) MORE than the reference value [growing FAST]
Height prediction: 117.9 cm (3 feet 10.4 inches) at 8 years
Mass-for-age 1.53 kg excess mass for age
(Weight-for-age) profile: (OVERWEIGHT for age by 3.38 lb)
Rate-of-mass-gain-for-age 0.13 kg/year (0.29 lb/year) MORE than the reference value
(weight-gain-for-age) profile: [rate HIGH]
Mass (Weight) prediction: 21.58 kg (47.5 lb) at 8 years
Obesity profile: Body-mass index (BMI) 1.57 kg/m² MORE than the reference value [OBESE]
Mass-for-height 2.07 kg EXCESS mass for height.
(Weight-for-height) profile: (OVERWEIGHT for height by 4.56 lb) [FAT]

Summary of Findings

The gap between reference height and actual height is DECREASING. However, A. S. is OVERWEIGHT both for age and for height.

Implications

The overweight condition may lead to cardiac problems. It may, also, cause early puberty, and, eventually, stunting.

Recommendations

A. S. must be, closely, watched for signs of trunk deformities on a regular basis, using visual and moiré examinations. She must indulge in fat-burning activities to control her weight.

Table 2 gives growth profile of Z. R., whereas parameters of growth prediction (6 months down the road) are listed in

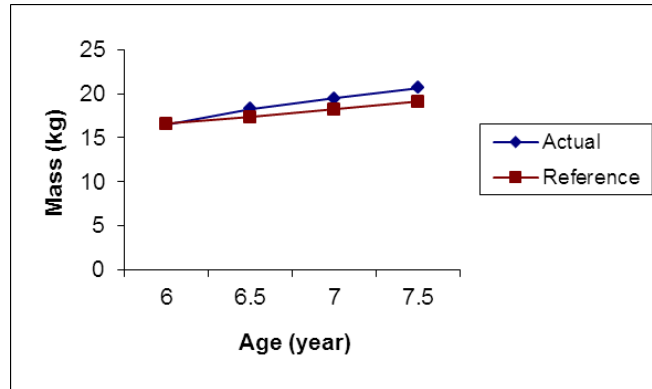


Fig. 3. Mass profile in graphical form

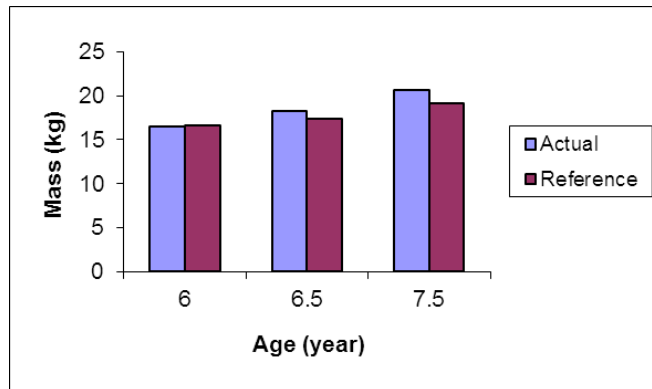


Fig. 4. Mass profile in bar-chart form

Table 3. Figures 3 and 4 show mass profiles of Z. R. in graphical as well as bar-chart forms, whereas Figures 5 and

Table 3. Growth prediction

Age	6 year 6 months	7 years	8 years
Height [cm]	108.9	110.6	117.9
Height [feet-inches]	3 feet 6.9 inches	3 feet 7.5 inches	3 feet 10.4 inches
Percentile-of-Height	3.8	< 3	4.4
Mass [kg]	17.54	20.80	21.58
Weight [lb]	38.67	45.85	47.5
Percentile-of-Weight	6.4	28.8	19.4

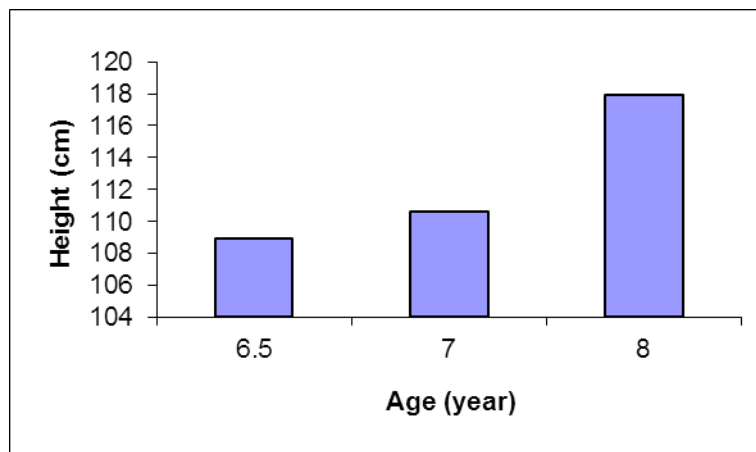


Fig. 5. Height prediction

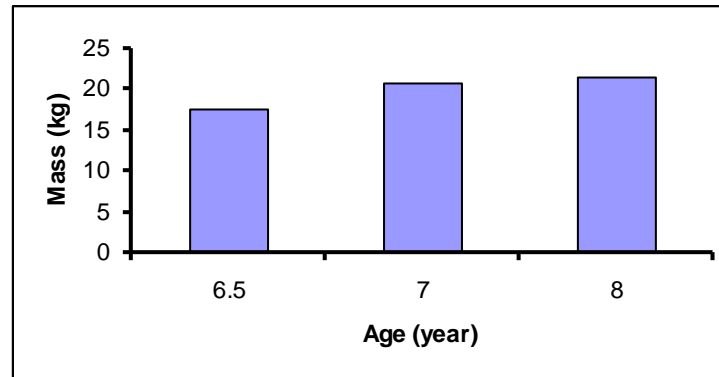


Fig. 6. Mass prediction

6 display height and mass predictions, respectively.

DISCUSSION

This pilot study was able to identify variables of interest and their interactions, elaborate response and involvement of the community, and the difficulties of data-collection in a conservative society. Further, it provided opportunities for community awareness, education and participation as well as initial step to develop formal human-right protocols of this part of world.

The software developed for growth analysis takes as input growth data of a child at 2 successive occasions 6-months apart, along with heights and weights of biological father and biological mother. The software generates as output a detailed growth profile of the child. The results are generated in a format easily understandable by parents and older children, avoiding technical jargon. In addition to the descriptive format, the information is made available in tabular form (for quick review by the attending pediatrician), in graphical form (for studying trend by the anthropometrist and the nutritionist) and in bar-chart form (for visual display, which may be helpful to parents with little or no education). The software shall be made accessible on the Internet for real-time processing of data. This information may prove valuable for pediatricians, nutritionists and physical-education instructors, who may, together, plan diet-cum-exercise programs, supplemented by medicines, if required, to achieve optimal height and weight. There is a dire need to accurately monitor growth of a child. 'Failure-to-Grow' is the first indicator of an underlying physical or emotional problem, which must be taken seriously requiring a head-to-toe examination as well as a psychiatric evaluation of the child.

Failure to intervene in childhood cases of stunting and wasting may result in 'short-height and underweight adolescents', eventually, producing 'underweight mothers'. These underweight mothers will, in turn, deliver 'low-birth-weight (LBW) babies', resulting in 'growth failure in childhood', and the cycle continues (Hunt, 2002).

The software is being tested in field studies conducted as part of the NGDS Pilot Project. Selected families are being studied in detail. Height and weight of parents is also recorded during the initial visit. The software is designed based on growth charts released by CDC (Center for Disease Control, Atlanta, Georgia, United States).

Future studies of growth should include somatotype as a factor to determine optimal mass (weight) for a given height (Kamal *et al.*, 2002d). Stereophotogrammetric techniques, such as, moiré fringe topography and rasterstereography (Kamal, 1998) may be helpful in documenting somatotypes.

ACKNOWLEDGEMENTS

We express our gratitude to Prof. Dr. Zulfiqar Ahmed Bhutta, the Aga Khan University Medical College (Karachi), for discussions at the planning stage, Prof. Dr. Bo S. Lindblad, Karolinska Institute (Sweden), for motivating and introducing to key researchers in the field, Dr. Johan Karlberg, Queen Mary Hospital, University of Hong Kong (Hong Kong), for providing a copy of his thesis. We would like to thank all children, their parents and principals for the participating schools (Army Public School, 'O' Levels, Karachi, Fazaia Degree College, PAF Base 'Faisal', Karachi, Bahria College, NORE I, Karachi) for their kind support. Last but not the least, we are indebted to Ex-Chancellor, University of Karachi, Lt. Gen. (Retd.) Moinuddin Haider, HI (M), for asking administrators of the participating institutions to extend coöperation for this study. This work was supported, in part, by Dean's Research Grant, University of Karachi, which is, sincerely, acknowledged.

REFERENCES

- Abolfotouh, M. A., H. A. H. Abu-Zeid, I. A. Badawi and A. A. Mahfouz (1993). A method for adjusting the international growth curves for local use in the assessment of nutritional status of Saudi pre-school children. *Journal of Egyptian Public Health*, 68 (5&6): 687-702
- Ayatollahi, S. M. T. (1993). Weight-for-height of South Iranian school children and the NCHS reference data. *International Journal of Obesity*, 17 (8): 471-474
- Edlund, B., P-O. Sjöden and M. Gebre-Medhin (1999). Anthropometry, body composition and body image in dieting and non-dieting 8-16 year-old Swedish girls. *Acta Paediatrica*, 88 (5): 537-44
- Hensinger, R. N. (1998). The challenge of growth: the fourth dimension of pediatric care. *Journal of Pediatric Orthopedics*, 18 (2): 141-144
- Hunt, J. (2002, February 14-17). Strategies for ending childhood malnutrition. *The 16th International Biennial Conference of Pakistan Pediatric Association*, Karachi, Pakistan, 2002, p. 24
- Kamal, S. A. (1982, April 26-29). Improvements in instruments for anthropometric measurements. *Bulletin of the American Physical Society*, 27 (4): 502, abstract: <http://www.ngds-ku.org/pub/confabst1.htm#C19>:
- Kamal, S. A. (1986). The relationship of anthropometric measurements taken on clothing to those taken on the body. *Karachi University Journal of Science*, 14 (1&2): 35-39, full text: <http://www.ngds-ku.org/Papers/J05.pdf>
- Kamal, S. A. (1998, January 1, 2). 3-D-optical imaging and image processing (biomedical applications). *Proceedings of International Workshop on Recent Advances in Computer Vision*, edited by J. R. Laghari, A. A. Naqvi, A. Q. Rajput, N. A. Sangi and M. A. Shah, SZABIST, Karachi, Pakistan, pp. 86-95, full text: <http://www.ngds-ku.org/Papers/C46.pdf>
- Kamal, S. A. (2002, September 23, 24). The Early Childhood Integrated Developmental Examination (ECIDE) for 3-8-year-old children. *The Aga Khan University National Health Sciences Research Symposium: Early Childhood Care and Development*, Karachi, Pakistan, p. 32, abstract#17: <http://www.ngds-ku.org/pub/confabst.htm#C54>:
- Kamal, S. A. and M. M. El-Sayyad (1980, October 26-28). An experimental verification of relation connecting the anthropometric measurements taken on the clothing to those taken on the body. *Proceedings of the Biomechanics Symposium*, Indiana University, Bloomington, Indiana, United States, edited by J. M. Copper and B. Haven, p. 346, abstract: <http://www.ngds-ku.org/pub/confabst1.htm#C09>:
- Kamal, S. A. and S. Firdous (2002a, February 14-17). The NGDS Pilot Project: Anthropometry of the Pakistani children. *The 16th International Biennial Conference of the Pakistan Pediatric Association*, Karachi, Pakistan, p. 127, abstract: <http://www.ngds-ku.org/pub/confabst.htm#C48>:
- Kamal, S. A. and S. Firdous (2002b, February 14-17). The NGDS Pilot Project: Modeling growth of the Pakistani children. *The 16th International Biennial Conference of the Pakistan Pediatric Association*, Karachi, Pakistan, p. 127, abstract: <http://www.ngds-ku.org/pub/confabst.htm#C47>:
- Kamal, S. A., S. Firdous and S. J. Alam (2002a, May31, June 1). The NGDS Pilot Project: Dealing with a complex system. *The Aga Khan University PGME Conference 2002: Complexity Science and Health Care*, Karachi, Pakistan, p. 5, abstract: <http://www.ngds-ku.org/pub/confabst.htm#C49>:
- Kamal, S. A., S. Firdous and S. J. Alam (2002b, September 23, 24). The NGDS Pilot Project: Aiming at the future of Pakistan. *The Aga Khan University National Health Sciences Research Symposium: Early Childhood Care and Development*, Karachi, Pakistan, p. 26, abstract: <http://www.ngds-ku.org/pub/confabst.htm#C53>:
- Kamal, S. A., S. J. Alam and S. Firdous (2002c, June 22). A precedence graph for the physical examination of children. *The National Telemedicine Conference Pakistan 2002*, Technology Resource Mobilization Unit (TreMU), Ministry of Science and Technology, Government of Pakistan, Islamabad, Pakistan, p. 2, abstract: <http://www.ngds-ku.org/pub/confabst.htm#C51>:
- Kamal, S. A., S. J. Alam and S. Firdous (2002d, June 22). The NGDS Pilot Project: A software to analyze growth of a child (a telemedicine perspective). *The National Telemedicine Conference Pakistan 2002*, Technology Resource Mobilization Unit (TreMU), Ministry of Science and Technology, Government of Pakistan, Islamabad, Pakistan, p. 2, full text: <http://www.ngds-ku.org/Papers/C52.pdf>
- Kamal, S. A., S. J. Alam and S. Firdous (2002e, May31, June 1). An influence graph for the physical examination of children. *The Aga Khan University PGME Conference 2002: Complexity Science and Health Care*, Karachi, Pakistan, p. 6, abstract: <http://www.ngds-ku.org/pub/confabst.htm#C50>:
- 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 Paediatrica Supplement*, 85 (417): 61-63
- Karlberg, J., Y. B. Cheung and Z. C. Luo (1999). An update on the update of growth charts. *Acta Paediatrica*, 88 (8): 797-802
- Magarey, A. M., T. J. C. Boulton, B. E. Chatterton, C. Schulz, B. E. C. Nordin and R. A. Cockington (1999). Bone growth from 11 to 17 years: Relationship to growth, gender and changes with pubertal status including timing of menarche. *Acta Paediatrica*, 88 (2): 139-146

- Moilanen, I. and P. Rantakallio (1989). The growth, the development and the education of Finnish twins: A longitudinal follow-up study in a birth cohort from pregnancy to nineteen years of age. *Growth Development and Aging*, 53 (4): 145-150
- Power, C., J. K. Lake and T. J. Cole (1997). Body-mass index and height from childhood to adulthood in the 1958 British birth cohort. *American Journal of Clinical Nutrition*, 66 (5): 1094-1101
- Rosner, B., R. Prineas, J. Loggie and S. R. Daniels (1998). Percentiles for body-mass index in US children 5 to 17 years of age. *Journal of Pediatrics*, 132 (2): 211-222

(Accepted for Publication: September 2004)

ADDITIONAL NOTES (related to this paper, but not part of the published manuscript)

i) The case presented in this paper is described in detail under the heading:

Growth Analysis — Case 1: An Obese Child
http://www.ngds-ku.org/ngds_URL/results.htm#Case_1

ii) Another case (of Z. L. Z.), representing sever wasting, is analyzed through the same mathematical tools and techniques. This case is available under the heading:

Growth Analysis — Case 2: A Severely Underweight Child
http://www.ngds-ku.org/ngds_URL/results.htm#Case_2

Detailed reports of this case are uploaded as:

Additional File 1 — Clinical Profile of Z. L. Z.
http://www.ngds-ku.org/Papers/J26/Additional_File_1.pdf
Additional File 2 — Growth Profile of Z. L. Z.
http://www.ngds-ku.org/Papers/J26/Additional_File_2.pdf

Web address of this document (first author's homepage): <http://www.ngds-ku.org/Papers/J26.pdf>

Abstract: <http://www.ngds-ku.org/pub/confabst.htm#J26>: