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AN INVESTIGATION OF GROWTH PROFILES OF THE PAKISTANI CHILDREN

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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, 2002*a*). This study was designed after taking into account complexities of the system and the operations (Kamal *et al.*, 2002*e*). 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' https://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

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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, 2002*a*, *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.*, 2002*c*), taking into account influences of different tests on results of each other (Kamal *et al.*, 2002*e*).

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

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.*, 2002*d*). 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.

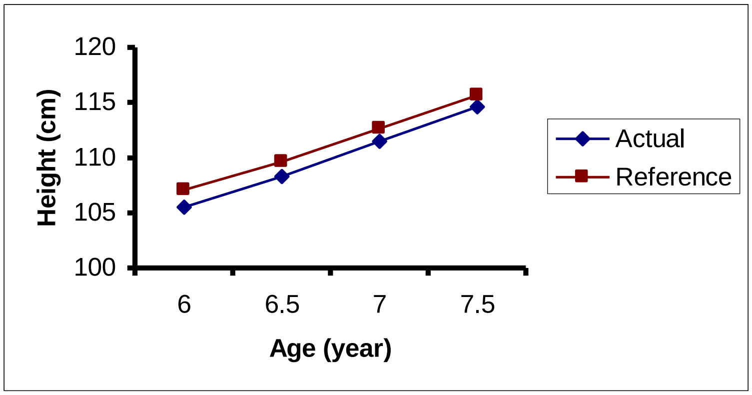

Fig. 1. Height profile in graphical form

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

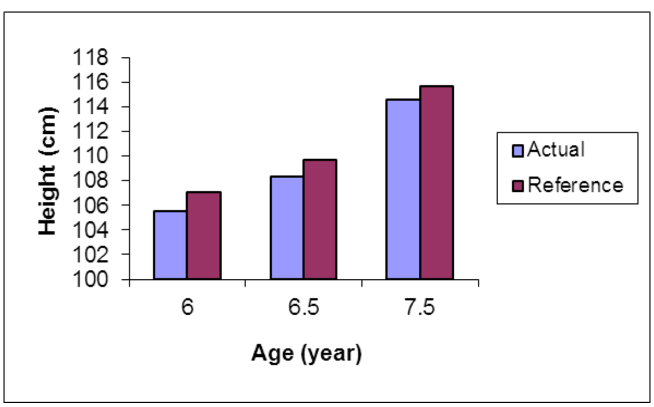

Fig. 2. Height profile in bar-chart form

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

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 (*Weight-for-age*) *profile*:	0.07 *kg* LESSER mass for age (UNDERWEIGHT for age by 0.16 *lb*)
Rate-of-mass-gain-for-age (*weight-gain-for-age*) *profile*:	0.08 *kg*/*year* (0.17 *lb*/*year*) LESSER than the reference value [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/m^2 MORE than the reference value [OBESE]
Mass-for-height (*Weight-for-height*) *profile*:	0.35 *kg* EXCESS mass for height (OVERWEIGHT for height by 0.76 *lb*) [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 (*Weight-for-age*) *profile*:	0.93 *kg* EXCESS mass for age (OVERWEIGHT for age by 2.04 *lb*)
Rate-of-mass-gain-for-age (*weight-gain-for-age*) *profile*:	3.27 *kg*/*year* (7.20 *lb*/*year*) MORE than the reference value [rate HIGH]
Mass (*Weight*) *prediction*:	20.80 *kg* (45.85 *lb*) at 7 *years*
Obesity profile:	Body-mass index (*BMI*) 1.61 kg/m^2 MORE than the reference value [OBESE]

Table 2. Growth profile

Δ (Growth Parameter) = Reference Value – Actual Value	**Between 1st and 2nd Checkup**	**Between 2nd and 3rd Checkup**	**Between 3rd and 4th 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 (*Weight-for-height*) *profile*: 1.89 *kg* EXCESS mass for height. (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 (*Weight-for-age*) *profile*: 1.53 *kg* excess mass for age (OVERWEIGHT for age by 3.38 *lb*)

Rate-of-mass-gain-for-age (*weight-gain-for-age*) *profile*: 0.13 *kg*/*year* (0.29 *lb*/*year*) MORE than the reference value [rate HIGH]

Mass (*Weight*) *prediction*: 21.58 *kg* (47.5 *lb*) at 8 years

Obesity profile: Body-mass index (*BMI*) 1.57 kg/m^2 MORE than the reference value [OBESE]

Mass-for-height (*Weight-for-height*) *profile*: 2.07 *kg* EXCESS mass for height. (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

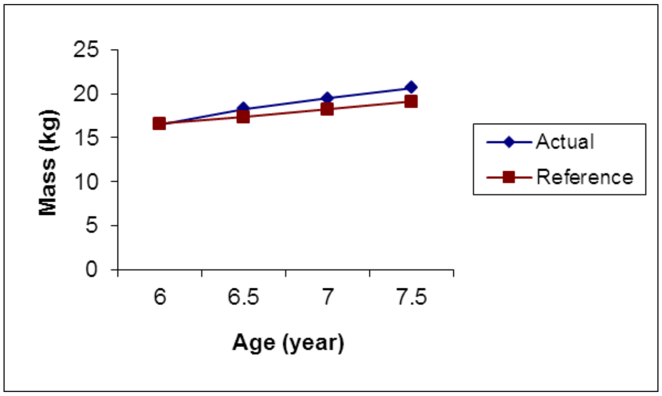

Fig. 3. Mass profile in graphical form

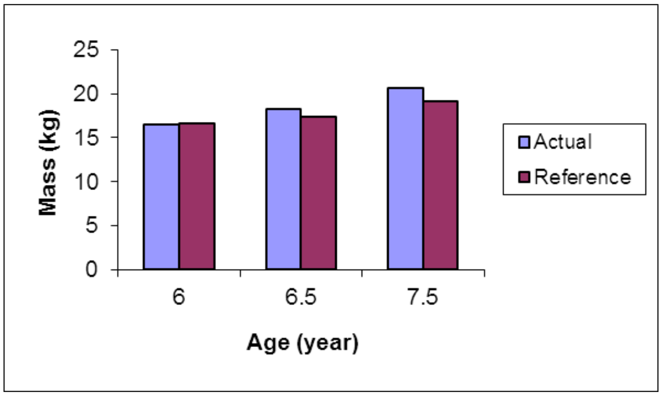

Fig. 4. Mass profile in bar-chart form

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^P	$< 3^P$	4.4^P
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

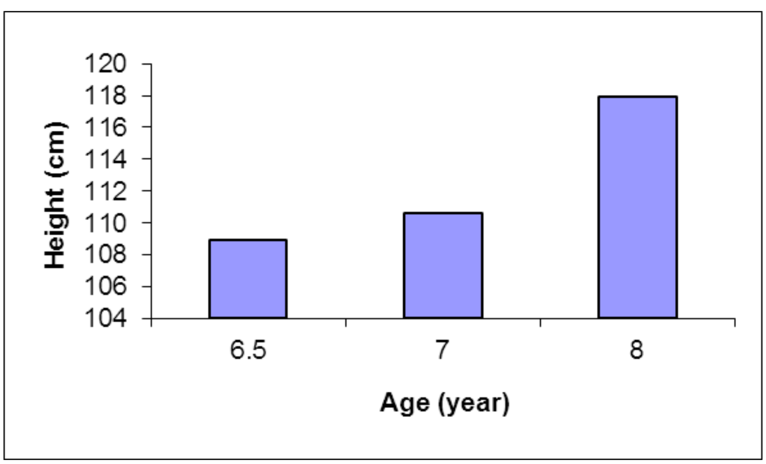

Fig. 5. Height predication

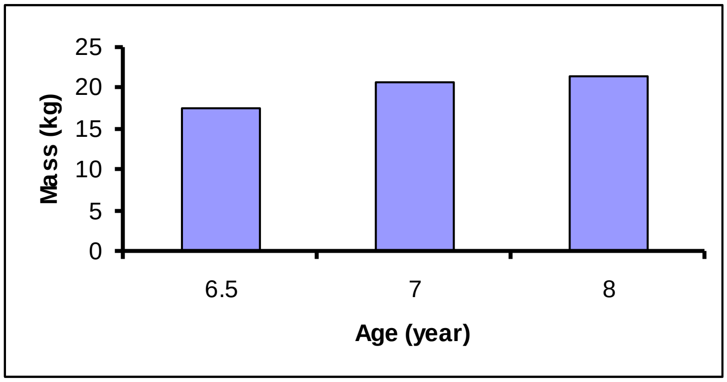

Fig. 6. Mass prediction

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 indictor 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.*, 2002*d*). Stereophotogrammetric techniques, such as, moiré fringe topography and rasterstereography (Kamal, 1998) may be helpful in documenting somatotypes.

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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

https://www.ngds-ku.org/ngds_URL/results.htm#Case_1

ii) Another case (of Z. L. Z.), representing severe 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

https://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.

https://www.ngds-ku.org/Papers/J26/Additional_File_1.pdf

Additional File 2 — Growth Profile of Z. L. Z.

https://www.ngds-ku.org/Papers/J26/Additional_File_2.pdf

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

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