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The NGDS Pilot Project: A Software to Analyze Growth of a Child (A Telemedicine Perspective)

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Aims and Objectives: *a*) To establish Pakistan-based anthropometric data library and growth charts.
b) To write softwares, which generate growth profile of a child.
c) To develop inexpensive anthropometry instruments from local resources.
Material and Methods: Protocols designed after taking into account North American and European ethi-cal and human-rights standards, employing opt-in policy. Standing and sitting heights, shoulder widths, weights and mid-upper-arm circumferences were measured on over 2000 healthy children.
Software Developed Indigenously: Software has been developed at the University of Karachi using Microsoft Visual Studio, Version 6.0, which takes as input heights and weights of biological parents, and those of child at 2 successive occasions, 6 months apart. The output is the 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 reference).
Instrumentation Developed Indigenously: Inexpensive instruments for height measurement as well as moiré frame for 3-D anthropometry, somatotyping and screening of trunk deformities were developed from local resources.
Results: Detailed growth analysis of child using software developed by the NGDS Team was presented. This software is to be made accessible, electronically, for remote processing of data.
Recommendations: Failure-to-grow may be the first indication of a major underlying problem. We recommend growth monitoring and analysis of all 3-10-year-old children using this software.

Keywords: anthropometry, 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, Cheung, Luo 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, El-Sayyad 1980).

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, Abu-Zeid, Badawi, Mahfouz 1993). Inadequate furniture in schools, offices and public transport is an indication of lack of national standards. University of Karachi, under the directives of Governor Sindh/Chancellor, University of Karachi, has taken up the task of establishing these standards. A Pilot Project has been started in 1998 to collect data on children, representing a national sample, in a better-than-average health. This project has the potential to identify variables of interest, their interactions, response and involvement of the community, and the possible difficulties of data-collection in a conservative society (Kamal, Firdous, Alam 2002*b*). This project shall, also, provide opportunities for community awareness, education and participation (Kamal 2001, 2002*a*) as well as develop formal human-right protocols for this part of world.

Research involving Minors

The NGDS Pilot Project Protocols were designed after taking into account of prevailing North American as well as European ethical and human-right standards:

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- The NGDS Pilot Project was initiated after 'Institutional Review Process' by University of Karachi authorities, which included committees of Chancellor (Governor Sindh) and Vice Chancellor.
- Afterwards, the project was reviewed by commanders of the Armed Forces of Pakistan and heads of the participating institutions.
- *Informed Consent Forms* https://www.ngds-ku.org/ngds_folder/Protocols/NGDS_Form.pdf, adhering to *Opt-in Policy*, requiring signatures of both parents and the students, were sent to the families and filled-in, signed slips collected back.
- Interactive sessions were held for school-health teams, teachers and students.
- Website was developed to keep in touch with the parents and provide them with the details of procedures in a language, understood by non-medical personnel https://ngds-ku.org
- Students were given detailed written and verbal instructions. They were shown the measuring equipment at least a day before actual measurements took place.
- Whenever possible, students were involved in mounting and in equipment handling to enhance their interest.
- Verbal consent was taken prior to check up and privacy of families respected.

Project Design

Design of this project is undertaken after extensive contacts with the local and the international experts as well as literature review comprising of growth studies in North America (Rosner, Prineas, Loggie, Daniels 1998), Europe (Edlund, Sjödén, Gebre-Medhin 1999; Moilanen, Rantakallio 1989; Power, Lake, Cole 1997), Asia (Abolfotouh, Abu-Zeid, Badawi, Mahfouz 1993; Ayatollahi 1993) and Australia (Magarey, Boulton, Chatterton, Schulz, Nor din, Cockington 1999), taking into account complexities of the system and the operations (Kamal, Firdous, Alam 2002*a*). Since 1998, the project is being successfully implemented at the **Army Public School**, 'O' Levels, Karachi, at the **Bahria College**, MT Khan Road, Karachi and at the **PAF Degree College**, Base 'Faisal', Karachi. These institutions are run by the Armed Forces of Pakistan. Hence, the children studying in these institutions represent all provinces and all localities. In general, they are in good health as compared to the average population. These children represent all socioeconomic groups, represented by education and by occupation of parents (consent-form slips request data regarding education and occupation of both parents as well as the size of nuclear family). The study sample, consisting of 3- to 10-*year*-old healthy boys and girls, studying in pre-primary and primary sections (classes 1-5) having no complications before birth and during the weaning period, seems to be ideal for establishing **National Growth and Developmental Standards (NGDS) for the Pakistani Children**. The growth profiles are being analyzed keeping in view the ICP model of growth (Karlberg 1987; 1996). The Early-Childhood-Integrated-Developmental Examination (ECIDE), which covers the age range 3-8 *years*, is to be administered to selected children (Kamal 2002).

Project Protocols

Barefoot standing heights, sitting heights, masses (weights), mid-upper-arm circumferences (MUAC) and shoulder widths were measured with the children undressed to short underpants, all clothing above the waist removed. Clothing left on the child (normally, briefs or panties) as well as behavior exhibited during the measurement was recorded on the structured chart. 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). For height measurement, an engineering tape mounted on the wall was utilized. Standing heights were recorded to the nearest millimeter with the child's back touching the tape, feet together, heels touching the wall, in attention position. Children were asked to breathe in and hold breath. A setsquare was used to read-off heights. A similar procedure was adopted for recording sitting heights. Mid-upper-arm circumferences were taken on both arms and compared. Shoulder widths were measured by asking the children to stand touching a wall and by placing setsquare on the free arm to record width. Masses (weights) were recorded to the nearest 0.5 *kg* using a bathroom scale, with the children instructed to breathe in, hold breath, and look at a pen held at the eye level, in stand-at-ease position (Kamal, Firdous 2002 *a*; *b*). The children suspected of having growth disorders were invited for a thorough evaluation in the Growth-and-Imaging Laboratory, where their masses were recorded on a calibrated beam scale to the nearest 0.1 *kg*.

Children were screened for factors, which may contribute to growth retardation. These included screening for anemia, cardiac disease and spinal curvatures, especially, scoliosis. The tests used to detect spinal curvatures are: visual inspection of back in anatomical and the mild-stretching positions, Adam's

Fig. 1*a-d*. From left to right, (*a*) height, (*b*) mass, (*c*) shoulder width and (*d*) MUAC measured in the Growth-and-Imaging Laboratory

forward bending and moiré fringe topography (Kamal 1998). A certain routine was devised and followed for the checkups (Kamal, Alam, Firdous 2002 *a*; *b*). Figure 1 illustrates some of the procedures performed in Growth Laboratory.

Software Development

Software is being developed using Microsoft Visual Studio, Version 6.0. 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, are coded 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.

Sample Results

A parent approached the NGDS Team for possible short stature of her daughter. Here are the measurements obtained during her four check ups:

Vital Statistics

Z. R. (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.

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*

History

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

Physical Examination

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. She exhibited 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. A moiré examination is scheduled at the time of her fifth checkup.

Table 1. 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

Anthropometry

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

Growth Profile[1]

Growth profile in tabular form is listed in Table 1.
*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]

Table 2. Growth prediction

Age	*6 years 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	3feet 10.4 inches
Mass [*kg*]	17.54	20.80	21.58
Weight [*lb*]	38.67	45.85	47.5

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]
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]

Table 2 lists growth-prediction parameters.

The case presented above is described in detail under the title, **Growth Analysis — Case 1: An Obese Child:** https://www.ngds-ku.org/ngds_URL/results.htm#Case_1

Another case, analyzed through the same mathematical tools and techniques, is available under the heading, **Growth Analysis — Case 2: A Severely Underweight Child:**
https://www.ngds-ku.org/ngds_URL/results.htm#Case_2

Clinical Profile of the above case is given at: http://www.ngds-ku.org/ngds_folder/Clinical_ZLZ.pdf, whereas *Growth-and-Obesity Profile* is uploaded at:
https://www.ngds-ku.org/ngds_folder/Growth_ZLZ.pdf

Summary and Discussion

The software developed for growth analysis takes as input growth data of a child at 2 successive occasions 6-*month* 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). The NGDS Software Development Group is working to make the results available 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). Anthropometric data from various centers may be transmitted electronically to 'The National Data Processing Center' (Kamal 2002*b*). The results may be sent back via electronic mail. Parents may also receive the results through this medium. At a later stage, the software may be made accessible on the internet for real-time pro-

cessing of data. This information may prove valuable for nutritionists, pediatricians and physical-education instructors, who may, together, plan diet-cum-exercise programs, supplemented by medicines, if required, to achieve proper height and optimal 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 (shorter height-for-age) and wasting (lesser weight-for-height) 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 2000).

The software is being tested in field studies conducted as part of the NGDS Pilot Project. Also, selected families are invited to participate in SGPP (the Sibling Growth Pilot Project), a subproject of the NGDS Pilot Project. All their children between the ages of 3 and 10 are monitored at 6-*month* interval. Parents are measured by the NGDS Anthropometrists. The software is designed based on growth charts released by CDC (Center for Disease Control, Atlanta, United States). The NGDS Team is working to make the software able to accept data from other growth curves, too. In future, selected international families are to be invited to participate in trials of the software.

Future studies of growth should include somatotype as a factor to determine optimal mass (weight) for a given height. Stereophotogrammetric techniques, such as, moiré fringe topography and rasterstereography (Kamal 1998) may be helpful in documenting somatotypes. Such studies may help devise an "Integrated Nutritional Education Program"[2].

Appendix: Dress and Behavior Codes

Dress Code

The amount of clothing present on a child effects measurements, examinations and observations. Therefore, a dress code is proposed for every measurement, examination and observation (Kamal 1998). The dress code is a fraction, numerator (denominator) of which represents amount of clothing superior (inferior) to transverse plane through the naval. Thus, 0 represents the absence of clothing and 3 the maximum amount of clothing. The following key may serve as a guideline. However, every examiner must set the code according to the environment and the style of clothing worn at the measurement setting. The codes used should be explained at the beginning of a report**:**

3/•	Fully dressed above waist	•/3	Fully dressed below waist
2/•	*V*, *dupatta*[3] or other head covering removed; dressed in shirt or *kameez*[4]	•/2	Shoes and socks removed; dressed in trousers, stockings or *shalwar*[5]
1/•	Undressed to undershirt	•/1	Undressed to shorts
0/•	Stripped to waist	•/0	Completely undressed below waist

A number in decimals would represent amount of clothing between two consecutive whole numbers. For example, a code 0/0.5, would indicate that the child is undressed to short underpants, all clothing above the waist removed (a practical clothing choice for anthropometric measurements of children), a dress code 0.5/0.5 may be indicative of upper undergarment kept on during the measurement, whereas a code 0/0 would mean the child is completely undressed, no covering of any kind. Sometimes, very young children refuse to remove leggings, socks or shoes, and the measurement has to be taken with these articles of clothing on. A dress code should indicate these non-standard procedures; *e. g.*, *L* following a dress code may represent presence of leggings, *S* stockings, *So* socks (if not removed), *Sh* shoes (worn during measurement) and *G* gown (if put on). For the measurement of parents, one may notice a code 1.5/1.5 (half-sleeved blouse, skirt), 2/2 (shirt, trousers) or (*kameez, shalwar* with head uncovered and *V*/*dupatta* removed), 2.5/2 (*kameez*, *V* or *dupatta*, *shalwar*), 3/3 (*Abaya* or *Burqa*[6] without head covering) 3.5/3 (*Abaya* or *Burqa* with head covering), etc.

In writing down procedures for anthropometric measurements of children, a recommended dress code, '*d*', is given based on practical considerations. If the optimum value of dress code, based on technical considerations, differs from the recommended value, it is, also, mentioned in brackets. The form, on which anthropometric measurement is recorded, must have a column to enter the actual dress code, '*D*', describing amount of clothing the child had on at the time of that particular procedure.

Behavior Code

The behavior code may have a numerical value 0 (relaxed and coöperative), 1 (timid and shy, but coöperative) and 2 (resistant and nagging). The optimum value for all the measurements is 0. In the procedures for measurement of height, weight and mid-upper-arm circumference, the maximum numerical value of behavioral state, '*b*', is given for which this procedure is permitted. The form, on which anthropometric measurement is recorded, must have a column to enter the actual behavior code, '*B*', the child was in at the time of that particular procedure. Note down if the procedure, itself, changed the behavior code. In order to perform measurements in the behavior code 0, it is suggested to brief and to demonstrate the procedures, beforehand. As undressing is essential for measurements of children, it is preferable that same-gender measurer performs these tasks.

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Footnotes

[1]Arshad Ali, Munsif Ali, Shazia Bibi, Ijaz Tanveer Husnain, Islamuddin, Kashif Majeed and Syeda Shabnam Shah performed preliminary, manual calculations for the first three check ups; Naveed Ahmed assisted in software development

[2]The term coined and the idea floated by Asha Bansari Hotchand

[3]*Dupatta* is a garment worn on shoulders (on top of *kameez*), sometimes covering head, generally, in the Indian subcontinent, the Middle East and the Far East

[4]*Kameez* is a garment worn on the upper portion of body, resembling a long shirt, generally, in the Indian subcontinent, the Middle East and the Far East

[5]*Shalwar* is a garment worn on the lower portion of body, resembling athletic trousers, generally, in the Indian subcontinent, the Middle East and the Far East

[6]*Burqa* or *Abaya* is an outer garment worn by females, mainly, in Muslim culture

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