BUILD DISTRIBUTION AMONG STUDENTS STUDYING IN INSTITUTIONS OF THE ARMED FORCES OF PAKISTAN

Syed Arif Kamal[*], **Shakeel Ahmed Ansari**[§] **and Ashfaq Ali Naz**[#]

The NGDS Pilot Project and ISST, University of Karachi, Karachi, Pakistan; *e-mail***:** profdrakamal@gmail.com

ABSTRACT

*Objective***:** To determine build distribution among school students to assist them in choosing suitable careers.
*Study Design***:** This was an anthropometric study.
*Place and Duration of Study***:** Initiated in 1998 in schools run by the Armed Forces of Pakistan (one each from Pakistan Army, Pakistan Navy and Pakistan Air Force); a civilian school added in 2011. Data reported covers the period 1998-2019.
*Material and Methods***:** Heights and masses of 1666 students (boys 503; girls 1163 — age range 3.20-14.63 *years*; mean 7.81 *years*; standard deviation 2.09 *years*) were measured, to least counts of 0.1 *cm* (1998-2011); 0.01 *cm* (2012-2015); 0.005 *cm* (2016 onward) and 0.5 *kg* (1998-2011); 0.01 *kg* (2012-2015); 0.005 *kg* (2016 onward), respectively, during the morning hours, following standardized protocols (ethical guidelines followed, students barefooted and undressed to short underpants (older girls in light indoor clothing), all clothing above the waist removed, equipments calibrated daily, measurer reproducibility documented), and modeled to generate Growth-and-Obesity Vector-Roadmap 2.6. In order to deal with extreme cases, CDC Growth Tables were extended using mathematical-statistical techniques to include percentiles 0.01^{P}, 0.1^{P}, 1^{P}, 99^{P}, 99.9^{P}, 99.99^{P} and adapted to be used for the Pakistani population by applying a scaling transformation linking medians of collected data of heights and masses to 50^{P} of modified-scaled percentiles. Build was determined from sum of modified-scaled percentiles of height and mass.
*Results***:** 436 students had small, 814 had medium and 416 had big builds.
*Conclusion***:** Youngsters are advised to take up careers based on their builds and estimated-adult heights — intelligence (small build), administration (medium build) and active combat (big build).

Keywords: *BMI*-based-optimal mass • estimated-adult *BMI* • estimated-adult height • Extended Growth Tables • Growth-and-Obesity Vector-Roadmap 2.6 • height-gain-target-achievement index • height-percentile-based-optimal mass • mass-management-target-achievement index • modified-scaled percentiles

LIST OF ABBREVIATIONS

BMI — body-mass index • CDC — Centers for Disease Control and Prevention, Atlanta, GA, United States • *dy* — day(s) • GR No. — general register number (stays same throughout the school period) • *mo* — month(s) • NGDS — National Growth and Developmental Standards for the Pakistani Children • ^{P} — percentile • *yr* — year(s)

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

INTRODUCTION

Anthropomety, a combination of Greek *anthropo* (human) and *metron* (measure), is the science of quantitative measurements of humans. It aims at collecting body-measurement data of high quality using laid-down procedures using calibrated equipment by reproducible anthropometrists.

This paper is based on a study, the NGDS Pilot Project, involving families belonging to the Armed Forces of Pakistan as well as families from the civilian sector to be able to advise their children for the most-suitable careers based on their builds determined from their heights and weights as well as computing their estimated-adult heights and comparing with adult-army-cutoff heights for the military and the paramilitary occupations in Pakistan (5 *ft* 4 *in* for males; 5 *ft* 2 *in* for females). In this exercise, the children were appraised on the importance of maintaining proper weight-for-height through suitable diet and exercise plans as well as adjustment of their lifestyle.

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[*]Meritorious Professor Dr. Syed Arif Kamal, PhD (Neuroscience); MA, Johns Hopkins, Baltimore, MD, United States; MS, Indiana, Bloomington, IN, United States; Ex-Acting Vice Chancellor and Ex-Dean, Faculty of Science, University of Karachi • *paper mail***:** Founding Project Director, the NGDS Pilot Project and Visiting Faculty, ISST, University of Karachi, PO Box 8423, Karachi 75270, Sindh, Pakistan • *homepage***:** https**:**//www.ngds-ku.org/kamal • *the NGDS Pilot Project URL***:** https**:**//ngds-ku.org

[§]PhD, MPhil, Associate Professor and Head, Department of Physics, Government Degree College for Boys and Girls, SRE Majeed, Stadium Road, Karachi 75350

[#]PhD, MPhil, Training Commander and Chief Education Officer, Pakistan Marine Academy, Hawksbay Road, Mauripur, Karachi 75780

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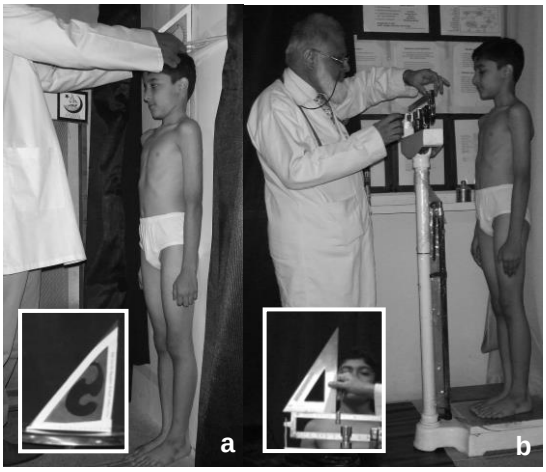

Fig. 1**.** Measuring (*a*) height and (*b*) weight (actually, mass) of a boy in Growth-and-Imaging Laboratory.

HEIGHT AND WEIGHT MONITORING OF SCHOOL-GOING STUDENTS

Height is an easily obtainable measure of life-course and long-run health. Height gain should be proportionate to give the look of a well-developed personality. Recently, weight and height trends were studied for the population of Crete Island before and after its annexation by Greece (Capocasa *et al*., 2019). In Pakistan, some recent anthropometric studies were conducted on 8-10-*year*-old girls in Bhawalpur district (Haq *et al*., 2019) as well as *BMI*s were investigated of school students of Dera Ismail Khan (Ramzan *et al*., 2008).

There are not many height-weight studies for military-age youth. Karpinos reported findings on height-weight data, extracted from medical-examination reports of potential recruits of United States, examined for service in the armed forces during January 1943 to January 1944 (Karpinos, 1958) and January 1957 to September 1958 (Karpinos, 1961). Of all the youngsters reporting for induction, those selected were taller and heavier.

For height measurement in schools, student was instructed to stand in attention position (full inhaling), chin parallel to floor, touching the mounted engineering tape and asked to align hands with body, palms touching thighs and heels together (Figure 1*a*). For recording of mass (weight), pupil was asked to step on the center of the beam scale in stand-at-ease position, palms on thighs and feet separated, looking straight and breathing in to trap maximum air (Figure 1*b*). Anthropometric measurements were performed as per laid-down procedures (Kamal, 2016); step-by-step protocols illustrated through labeled photographs (Additional File 1 of Kamal *et al.*, 2021*a*). Mass- and height-measurement instruments were calibrated using standard 2-*kg* mass and 100-*cm* ruler at the start of each daily session along with recording of zero errors.

OBESITY IN YOUNGSTERS

Body-mass index (*BMI*), reported in kg/m^2, is computed by dividing mass (in *kg*) by square of height (in *m*); 24 kg/m^2 is taken as reference (Keys *et al.*, 1972). *BMI* range, used for estimating statuses for adults, cannot be employed for children (Kamal *et al.*, 2013). One needs *BMI* tables to determine *BMI* percentiles used to classify youngsters as obese or wasted — lesser weight-for-height (Kamal *et al.*, 2017*c*). Alternatively, one may compute estimated-adult *BMI* (masses and heights replaced by their estimated-adult values), which can be used for younger population in the same way one uses *BMI* for adults (Kamal and Jamil, 2012). Researchers have been attempting to define childhood obesity since the last century (Poskitt, 1995; 2001; Cole *et al.*, 2000). With the passage of time, a child is gaining height as well as mass. Hence, measured values of height and mass are unable to indicate true status of obesity in children. The first author defined 'true obesity' as the condition in which a child was required to shed off mass within a period of 6 *months* based on applicable model of growth and obesity (Kamal, 2017).

Ludwig (2007) discussed long-term effects of obesity epidemic (now became pandemic) in 4 phases. Phase I has excessive cases of obesity due to little awareness. Phase II should be associated with serious medical conditions as type-II diabetes, fatty lever and psychosocial problems. In Phase III, life-threatening diseases, like coronary heart disease and kidney failure is supposed to shorten life expectancy of population of United States. In Phase IV, the prevalence of such diseases is projected to further increase resulting in non-genetic influences in the offspring. In an e-communication to Rafia Imtiaz (student of the first author), Ludwig elaborated**:** "Phase IV of the epidemic would develop slowing over time, as obese children grow up and give birth to the next generation of children."

Natale *et al.* (2014) emphasized the need of role modeling as a strategy to prevent early childhood obesity by involving parents and teachers to develop healthy lifestyle habits in preschool children. Greydanus *et al*. (2018)

described history, definition, epidemiology, diagnostic perspectives, psychological considerations, musculoskeletal as well as endocrine complications and principles of management related to obesity in youngsters. Akram *et al*. (2018) explained the impacts of behavioral, environmental and social factors on obesity. Kumar and Kelly (2018) reviewed epidemiology, etiology, comorbidities and clinical assessment of childhood obesity. Bramante *et al*. (2019) described natural experiments for childhood obesity prevention and control. Brock *et al*. (2019) looked into the ways of building and sustaining capacity to address obesity in children.

THE NGDS PILOT PROJECT

As per directives of Governor Sindh/Chancellor, University of Karachi, a retired Lieutenant General of the Pakistan Army, a team from University of Karachi, led by the first author (SAK), took up the assignment to establish National Growth and Developmental Standards (NGDS) for the Pakistani children. In 1998, this team initiated the NGDS Pilot Project in 3 institutions administered by the Armed Forces of Pakistan — Army Public School, 'O' Levels, Fazaia Degree College, PAF Base 'Faisal' and Bahria College, NORE I, all located in Karachi, on the basis of letters from the Secretariat of Governor Sindh, bearing numbers GS/2-55/98 (SO-I)/2531, 2530 and 2529, all dated November 25, 1998, addressed to HQ 5 Corps, Commanding Officer, Bahria Complex, NORE I and Base Commander, PAF Base 'Faisal', respectively. In 2011, a civilian school (Beacon Light Academy, Karachi) was included in the study. The NGDS Pilot Project was convened following protocols of 'Institutional Review Process', which included applicable human-right and ethical standards for this region (Additional File 1 of Kamal *et al.*, 2016*a*). 'Opt-in policy', was used for participation, requiring parents to complete and sign 'Informed Consent Form'. Examinations were conducted taking care of comfort, confidentiality, dignity, privacy and safety of students. Due attention was paid to posture (knees joining), detection of scoliosis using visual examination, Adam's forward bending test, moiré fringe topography and dotted-rasterstereography as well as gait (Kamal *et al.*, 2016*b*) during walking (toes inward/outward) and running (knees knocking). In addition, estimated-adult height was computed for each student to find out whether the individual was able to qualify for induction in the Armed Forces of Pakistan or not (Kamal *et al.*, 2017*c*). Students' data (demographic and clinical) were entered in a structured form. Name, birth date, gender, education and occupation of parents as well as siblings' details were included in the demographic data.

Statuses pertaining to heights and masses as well as recommendations to achieve height and maintain mass during the next 6 *months* of a child, Hr. S., were earlier computed using Growth-and-Obesity Vector-Roadmap 1.1 (Kamal *et al.*, 2017*c*). The techniques have now been fine-tuned and calculations could be performed using Growth-and-Obesity Vector-Roadmap 2.6 — detailed method of construction of Roadmap 2.6 is included in Additional File 3 of Kamal *et al.* (2021*a*). Roadmap 2.6 of Hr. S. is made available in Appendix A. It would be of interest to compare these results with those of Roadmap 1.1 included in Kamal *et al*. (2017*c*).

SALIENT FEATURES

The unique features and accomplishments of the NGDS Pilot Project, now in the 24th *year* since its inception, are summarized below**:**

- Procedures established (Figures 1*a*, *b*), documented — manual developed (Kamal, 2016) as well as step-by-step, illustrated and labeled instructions prepared (Additional File 1 of Kamal *et al.*, 2021*a*) and validated for height measurements to least counts of 0.1 *cm* (1998-2011) — setsquare set; 0.01 *cm* (2012-2015) — Vernier scale; 0.005 *cm* (2016 onward) — enhanced-Vernier scale and mass (weight) measurements to least counts of 0.5 *kg* (1998-2011) — bathroom scale; 0.01 *kg* (2012-2015) — modified-beam scale; 0.005 *kg* (2016 onward) — enhanced-beam scale (Kamal *et al.*, 2016*a*); CDC Growth Charts and Tables extended to percentile range 0.01^{P}-99.99^{P} (Kamal and Jamil, 2014), scaled percentiles (Kamal *et al.*, 2017*b*) and modified-scaled percentiles introduced (Kamal *et al.*, 2021*a*).
- For aspiring youngsters dreaming to serve their country through enlistment in the military and the paramilitary occupations, model and software computed estimated-adult height and difference of measured height and current-age-army-cutoff height; 6 monthly recommendations for height gain given to students (Kamal *et al.*, 2016*a*) and height-gain-target-achievement index (Kamal *et al.*, 2020*a*) computed based on current and previous checkups.
- The first- to the ninth-generation solutions of childhood obesity put forward (Kamal *et al.*, 2021*b*).
- Concepts of energy channnelization (Kamal *et al.*, 2014), estimated-adult *BMI* (Kamal and Jamil, 2012), specific *BMI* (Kamal *et al.*, 2020*a*), degree of obesity/wasting and tallness/stunting (Kamal *et al.*, 2011) as well as pseudo-gain of height/mass introduced (Kamal *et al.*, 2014).
- Definitions of true obesity/wasting/tallness/stunting as well as instantaneous obesity/wasting/tallness/stunting given [true obesity (Kamal, 2017); true wasting (Kamal *et al.*, 2017*a*); true tallness and true stunting (Kamal *et al.*, 2021*b*)]; 6 monthly recommendations for mass management, on the basis of height-percentile-based-optimal mass (Kamal *et al.*, 2011) and *BMI*-based-optimal mass (Kamal, 2017), provided to students and mass-management-target-achievement index (Kamal *et al.*, 2020*a*) computed based on current and previous checkups.

Table 1. Descriptive statistics — qualitative and quantitative.

Data Collected during *1998-2019*	*Boys* ♂	*Girls* ♀
Total Number	503	1163
Age		
Mean ± Standard Deviation (*years*)	6.21 ± 1.70	8.51 ± 1.85
Median (*years*)	6.27	8.64
Mode (*years*)	6.68	8.27
Range (*years*)	3.20-12.07	5.01-14.63
CDC Percentile of Height		
Median	43.21272955[P]	34.85247886[P]
CDC Percentile of Mass		
Median	22.99109832[P]	19.92558247[P]

- Nutritional-status categories extended to 23 (Kamal *et al.*, 2021*b*) from 3 categories in literature before 2014**:** acute malnutrition, over-nutrition and under-nutrition described in Kamal *et al.* (2014).
- Mathematical expressions to compute severity of acute malnutrition in terms of CDC percentiles of height and mass (Kamal, 2015) and afterwards in terms of scaled percentiles (Kamal *et al.*, 2017*b*) given.

DETERMINATION OF BUILD

Kamal and Khan (2015) proposed mathematical criteria to assign build to an individual based on sum of CDC percentiles of height and mass, which was, later, upgraded to sum of scaled percentiles (Kamal *et al.*, 2017*b*). Modified-scaled percentiles (Kamal *et al.*, 2021*a*) are to be used in place of CDC percentiles for the Pakistani youth. For 'small' build, this sum is less than 50. For 'medium' build, this sum is equal to or more than 50 but less than 150. For 'big' build, this sum is equal to or greater than 150. Sport teams as well as classroom sections are formed according to build (Kamal and Khan, 2018).

Brain dominates body in persons with small build, making them more suitable for intellectual work as well as tasks involving planning and development. Body dominates brain in persons with big build, which helps them accomplish tasks involving strength and speed. Brain and body are equally contributing in persons with medium build. They may adapt to body- or brain-dominating tasks, depending on their training (Table 3 of Kamal, 2015).

MATERIAL AND METHODS

Heights and masses of 1666 students (boys 503; girls 1163 — age range 3.20-14.63 *years*; mean ± standard deviation 7.81 ± 2.09 *years*) were measured during the first half of the day, following agreed-upon protocols**:** ethical guidelines followed, students barefooted and undressed to briefs/panties (older girls in school uniforms), everything above the waist taken off, equipments calibrated at the start of each day, reproducibility of anthropometrists documented. Gender-based breakdown of descriptive statistics is available in Table 1. This convenience sample was collected during 1998-2019 and analyzed to determine distribution of builds.

A software developed indigenously, SOFTGROWTH 2.6 (flowchart included in Appendix B), was used to generate Growth-and-Obesity Vector-Roadmaps 2.6 (Kamal *et al.*, 2021*a*) of students. For shorter calculations, an anthropometric calculator, developed by the NGDS Team, was used (Figure 2). This calculator comprises of 6-bar menu**:**

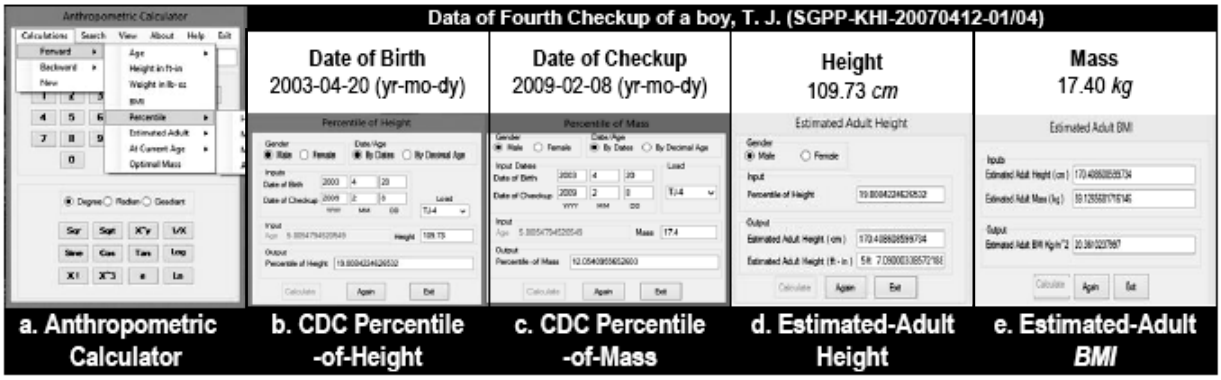

Fig. 2. 'Anthropometric Calculator' displaying computations of T. J.

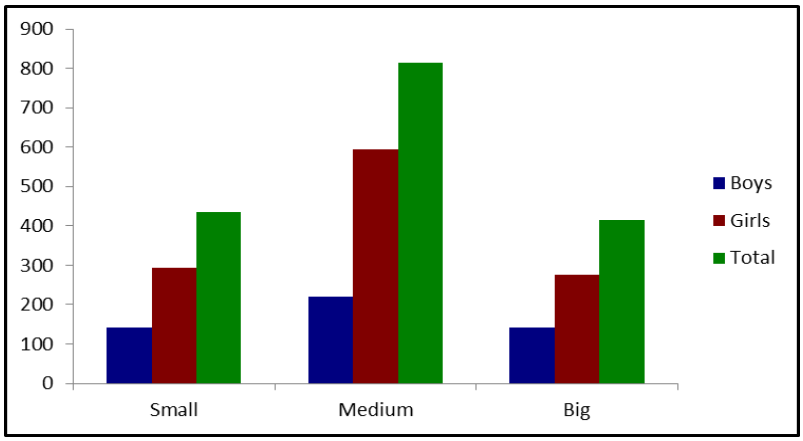

Fig. 4. Bar chart showing distribution of builds

a) Calculation — It consists of forward and backward options; forward option calculates anthropometric parameters, *i. e.*, age, *BMI*, estimated-adult *BMI*, different percentiles (CDC height, CDC mass, mid-parental height, army-cutoff height), various heights (estimated adult, current-age-mid-parental, current-age-army-cutoff) and masses (estimated adult, optimal).
b) Search — This option is used to search values for a certain gender-specific height/mass from extended growth tables (Additional File 3 of Kamal and Jamil, 2014) by giving age grid and percentile grid.
c) View — All growth charts can be viewed quickly by using this option.
d) About — This option provides a brief description of the NGDS Pilot Project, research activities, research group and software.
e) Help — This option includes standard values and conversion formulae.
f) Exit

RESULTS

436 students — 26.17% of 1666 students (142 boys — 25.83% of 503 total boys; 294 girls — 25.28% of 1163 total girls) are found to be of small build, 814 students — 48.86% (220 boys — 43.74%; 594 girls — 51.07%) are determined to be of medium build and 416 students — 24.97% (141 boys — 28.03%; 275 girls — 23.65%) are classified as having big build. Figure 4 displays bar chart of distribution of builds.

RECOMMENDATIONS

The causes, consequences and solutions of obesity pandemic have been discussed again and again, but do we have the will to prevent childhood obesity (Meldrum *et al.*, 2017)? Following are the recommendations from the authors in this regard**:**

- Regular height and weight monitoring and generation of Growth-and-Obesity Roadmaps 2.6 (Kamal *et al.*, 2021*a*), on a 6-monthly basis, should be made compulsory in all schools and colleges run by the Armed Forces of Pakistan and later in all public and private sector schools. Lifestyle adjustment, diet and exercise plans should be provided to students to help them achieve height-gain as well as mass-management targets (Additional File 4 of Kamal *et al.*, 2021*a*).
- There should be incentives to achieve the above-mentioned targets through certificates, stars and honor rolls (Kamal *et al.*, 2017*c*).
- It is better not to base the decision to induct in the Armed Forces of Pakistan on the results of a single measurement of height and weight, but on a collection of Growth-and-Obesity Roadmaps 2.6 (Kamal *et al.*, 2021*a*) showing the candidate's progress over at least 5 *years* prior to reporting for recruitment (Kamal *et al.*, 2017*c*).
- Physical-education instructors should be trained to obtain measurements of height and weights of students as per laid-down procedures (Kamal, 2016).
- Testing for vitamin-D level should be performed biannually and students exposed to fresh air and sunshine on a daily basis (Kamal and Khan, 2018).
- Once a year the students should be subjected to psychological examination, stripped-physical examination concentrating on risk of acquiring scoliosis (Kamal *et al.*, 2020*b*) as well as fitness testing (Kamal *et al.*, 2017*b*).

- Gymnastics should be made compulsory for students of classes 1-10 (Kamal and Khan, 2015). This should help strengthen their spinal columns with necessary flexibility.
- Students should be provided ample opportunities (Iqbal *et al.,* 2020) to participate in sport (athletics, cricket, football, gymnastics, squash, tennis, *etc.*) through sport academies operated as per SOPs established to safeguard their health in the wake of corona pandemic (Kamal and Khan, 2020) as well as summer camps to teach them life skills in addition to sport coaching (Kamal and Khan, 2021). Such activities should help reduce aggression and prevent depression in students.

FUTURE DIRECTIONS

Following are the future directions of research, which may find applications in health surveillance of personnel of the Armed Forces of Pakistan and their immediate families**:**

- Preparation of calorie-wise quantitative diet plans to achieve 6 monthly height-gain and mass-management targets.
- Formulation of customized exercise plans to achieve 6 monthly height-gain and mass-management targets.
- Enhancement of anthropometric instruments to measure heights and masses to least counts of 0.001 *cm* and 0.001 *kg*, respectively, as well as increasing reproducibility following the lines of action proposed elsewhere (Kamal *et al.*, 2016*a*).
- Development of the Pakistani Growth Charts and Tables with data collected nationally based on standardized protocols covering age range from birth to 60 *years* (not merely 2-20 *years* — percentile-wise weight distribution in a 20-*year* old is not the same as that in a 60-*year* old), work already initiated by some groups (Aziz *et al.,* 2012).
- 2 calibration equations (one for boys and the other for girls) to be obtained for conversion of recumbent length (measured till the age of 2 *years*) and standing height (2 *years* onward) based on collected data of the Pakistani children of recumbent length and standing height in the age range 3-10 *years*.
- Adaptation of formulae to compute target height based on indigenous data. Formulae, currently in use, are based on the British data (Tanner *et al.,* 1970).
- Modeling of expanded and unexpanded chest circumference from a very young age to help students achieve the required expansion, when they grow into young adults; measurement of waist circumference and hip circumference to include over-fat condition in addition to over-weight condition.

DISCUSSION AND CONCLUSION

In this paper the authors have determined build distribution of a representative sample of the Pakistani students hailing from all provinces enrolled in institutions run by the Armed Forces of Pakistan as well as a civilian school. Careers most suitable for these students, based on their builds, are intelligence (small build), administration (medium build) and active combat (big build).

Active prevention is recommended by maintaining weight as per recommended monthly target ranges through a combination of lifestyle changes as well as customized diet and exercise plans.

Taking the concepts from energy projects, Pakistan should have child-health-care generation (modeling of child growth-and-obesity), transmission (software, manual, training programs made available to school-physical-education instructors and community-health workers) and distribution (child growth-and-obesity surveillance in school and community health units) to achieve a healthy nation. It is through improving physical and psychological health as well as fitness level of the youth of Pakistan that the dream of making this country a regional power could be materialized.

KEY POINTS

- The pre-requisite for induction in the Armed Forces of Pakistan is minimum height of the individual, which is 5 *feet* 4 *inches* (CDC percentile of height**:** 2.72^{P}) for males and 5 *feet* 2 *inches* (19.36^{P}) for females.
- The authors have developed methods to generate Growth-and-Obesity Roadmaps of still-growing youth, which can determine estimated-adult height of a child from the very tender age, allowing sufficient time for intervention.
- Career assignment of an inductee should be based on build of an individual (small, medium or big), which is determined from sum of modified-scaled percentiles of height and mass.
- Builds of 1666 students (boys 503; girls 1163) were computed using Growth-and-Obesity Vector-Roadmaps 2.6.
- 436 students possessed small build (suitable for intelligence careers), 814 medium (suitable for administrative work) and 416 big build (suitable for active combat).

DEDICATION

The authors would like to dedicate this paper to the loving memory of their very dear friend and co-worker, Mohummed Javed Ansari (Wednesday, May 10, 1961; Karachi - Wednesday, August 8, 2021; Karachi). He obtained his B. Sc. (Mathematics, Physics and Geology), M. Sc. (Applied Mathematics) and M. Phil. (Mathematics) from University of Karachi. He joined University of Karachi as Coöperative Teacher in 1991. In 2000, he was appointed Assistant Professor in Department of Mathematics. During his tenure in Department of Mathematics, he has been actively involved in activities of the department in particular and university in general. He was Students' Advisor for the departmental committee for more than 10 years. He was, also, member of Students' Advisory Committee of University of Karachi for more than 7 years. Other committees on which he served are Admissions Committee, Convocation Committee and Committee to run the affairs of Semester Examination Section. He was a member of statuary bodies — Board of Studies of Mathematics and Board of Faculty of Science. For 2 years, he worked as Controller of Examinations. He is survived by his wife, two sons and two daughters. The authors of this paper wrote 2 papers jointly with the deceased (Kamal *et al.*, 2020*a*; 2021*a*). The university community is shocked by his untimely death. May Allah, *Izz-o-Jal*, rest his soul in eternal peace!

APPENDIX A: GROWTH-AND-OBESITY VECTOR-ROADMAP 2.6 OF Hr. S.

In this appendix, we present Growth-and-Obesity Vector-Roadmap 2.6 of Hr. S. Figure 5 gives highlights of history and physical examination. In order to protect privacy of child, the initials given here do not correspond to the first, the middle and the last name of child, but are connected to the real name through a logical relationship. The case number shown in Figure 5 is not the case number appearing in the report given to child's parents, but both of these case numbers are related through a mathematical transformation. The same is, also, true for GR No. In Table 2*a*, photographs inserted do not show the actual child and signatures are replaced by pseudo-initials.

On the following pages, Growth-and-Obesity Vector-Roadmap 2.6 of Hr. S. is presented (Tables 2*a*-*d*). Table 2*a* gives 3 profiles, generated from examinations, when the child was studying in classes I, II and III, respectively. In Table 2*a* one notices that **pseudo-gain of height** is exhibited between 2nd and 3rd checkups — height pick-up from **124.53 *cm*** to **126.45 *cm***, CDC height percentile dropping from **27.08^{P}** to **23.09^{P}**; **pseudo-gain of mass** exhibited between 2nd and 3rd checkups — mass put-on from **21.90 *kg*** to **22. 53 *kg***, CDC mass percentile dropping from **14.74^{P}** to **10.30^{P}**. The phenomenon of pseudo-gain of height (mass) was first defined in Kamal *et al.* (2014). Pseudo-gain of height is present, when height gain is accompanied by a drop in CDC percentile-of-height for 2 consecutive checkups, with a similar definition for

Hr. S. (NGDS-BLA-2011-4974/H; SGPP-KHI-20110614-01/01)
*Hr. S.***:** Female, 7+ at the first checkup, biological child, blood group B+
*Family History***:** Cousin marriage; paternal grandfather cardiac patient; severe scoliosis in paternal cousin; father, grand parents diabetics
*Pregnancy, Delivery and Neonatal***:** Pregnancy normal, forceps delivery after 37 *weeks* of pregnancy, jaundice at birth, breast-fed for one *month*, birth length not available, birth mass (weight) 3 *kg*
*Sleep Pattern and Diet Habits***:** 9-*hour* sleep, 2 meals (relaxed), 1 or none snack
*Academics***:** Excellent
*Co-Curricular Activities***:** Good
*Social Interaction with Teachers, Peers and Family***:** Better, dependent, shy
*Routine Health Surveillance***:** Last checkup 6 *months* ago (at the time of first visit to Growth-and-Obesity Laboratory)
*Physical Examination***:** During all her 3 checkups (first checkup in Growth-and-Obesity Laboratory, second and third checkups in school), Hr. S. was examined completely undressed wearing only panties (barefoot, stripped-to-waist) to thoroughly check nutritional status, posture, gait and presence of trunk deformities (scoliosis, kyphosis and lordosis). At the time of first checkup school bag was not brought; child smartly dressed; visual, forward bending and moiré examinations of the spinal column performed; umbilical cord not properly cut; hair dry; white spots on nails; teeth yellow; normal heart sounds (standing and squatting); gait with toes inward; positive Trendelenburg sign (right); positive forward bending (opposite sides from front and back); back posture**:** left shoulder drooping, left scapula down, and body triangles unequal, spinal dimples level, midline of back showing S curve (not corrected upon mild stretching); front posture**:** right shoulder drooping, right nipple down

Fig. 5. History and physical examination of Hr. S.

Table 2*a***.** Growth-and-Obesity Vector-Roadmap 2.6 of Hr. S. (*GR No.* — 4974)

*Gender***:** Female ♀ • *Date of Birth* (*year-month-day*)**:** 2005-04-10 • *Adult-Army-Cutoff Height***:** 157.48 *cm* (19.36^{P})

*Father's Height***:** ♂ 172.01 *cm* • *Mother's Height***:** ♀ 162.94 *cm* • *Target Height***:** 160.975 *cm* (36.49^{P})

Checkup	*1st*	*2nd*	*3rd*
Photograph			
Scanned Signatures	*HrS*	*HrS*	*HrS*
Class	I	II	III
Date of Checkup (*year-month-day*)	2012-07-15	2013-05-15	2013-11-21
Time of Checkup (24-*hour* clock)	1015h	0900h	0915h
Age (*year-month-day*)	07-03-05	08-01-05	08-07-11
Age (*decimal years*)	7.26	8.10	8.62
Dress Code$^{\gamma}$	0/0.5$^{\gamma}$	0/0.5$^{\gamma}$	0/0.5$^{\gamma}$
Behavior Code$^{\gamma}$	0$^{\gamma}$	0$^{\gamma}$	0$^{\gamma}$
Puberty Rating	Tanner 1	Tanner 1	Tanner 1
Height (*cm*) ⇐	119.36	**124.53**	**126.45**
Height (*ft-in*)	3 *ft* 10.99 *in*	4 *ft* 1.03 *in*	4 *ft* 1.78 *in*
CDC Percentile-of-Height ⇔	24.63^{P}	**27.08^{P}**	**23.09^{P}**
Modified-Scaled Percentile-of-Height	37.02^{P}	40.25^{P}	34.93^{P}
Current-Age-Army-Cutoff Height (*cm*) ⇐	118.25	122.99	125.64
Δ Height *w. r. t.*$^{\lambda}$ Current-Age-Army-Cutoff Height (*cm*)	+1.08	+1.54	+0.81
Current-Age-Mid-Parental Height (*cm*) ⇐	121.15	126.00	128.76
Δ Height *w. r. t.* Current-Age-Mid-Parental Height (*cm*)	–1.79	–1.47	–2.29
Estimated-Adult Height (*cm*)	158.87	159.33	158.46
Estimated-Adult Height (*ft–in*)	**5 *ft* 2.55 *in***	**5 *ft* 2.23 *in***	**5 *ft* 2.39 *in***
Modified Status (pertaining-to-height)	0	0	0
Descriptive Status (pertaining-to-height)	**Normal**	**Normal**	**Normal**
Net Mass (*kg*) ⇒	19.19	**21.90**	**22.53**
Net Weight (*lb-oz*)	42 *lb* 5.02 *oz*	48 *lb* 4.63 *oz*	49 *lb* 10.86 *oz*
CDC Percentile-of-Net-Mass ⇔	8.13^{P}	**14.74^{P}**	**10.30^{P}**
Modified-Scaled Percentile-of-Net-Mass	28.70^{P}	41.93^{P}	33.50^{P}
Percentile-of-*BMI*-based-Optimal-Mass ⇔	57.71^{P}	58.86^{P}	56.70^{P}
BMI-based-Optimal-Mass (*kg*) ⇒	24.39	27.16	28.67
Δ Mass *w. r. t. BMI*-based-Optimal-Mass (*cm*)	–5.20	–5.26	–6.14
Height-Percentile-based-Optimal Mass (*kg*) ⇒	21.15	23.47	24.39
Δ Mass *w. r. t.* Height-Percentile-based-Optimal Mass (*cm*)	–1.96	–1.57	–1.86
Estimated-Adult Mass (*kg*)	47.60	49.68	48.46
Estimated-Adult Weight (*lb–oz*)	104 *lb* 15.37 *oz*	109 *lb* 8.67 *oz*	106 *lb* 13.82 *oz*
Modified Status (pertaining-to-mass)	–9.28%	–6.68%	–7.61%
Descriptive Status (pertaining-to-mass)	**1st-Degree Wasted**	**1st-Degree Wasted**	**1st-Degree Wasted**
Away-from-Normality Index	0.0928	0.0668	0.0761
Polar Angle (*degree*)	180.00^{o}	180.00^{o}	180.00^{o}
Extended Nutritional Status	**Wasted**	**Wasted**	**Wasted**
Estimated-Adult *BMI* (*kg*/*m*^{2})	18.86	19.57	19.30
Estimated-Adult-Specific *BMI*	0.786	0.815	0.804
Build	**Medium**	**Medium**	**Medium**

$^{\gamma}$'Dress Code' 0/0.5 implies that Hr. S. was measured wearing panties only, barefoot, all clothing above the waist removed; 'Behavior Code' 0 means that Hr. S. was relaxed and coöperative (Kamal, 2016)

$^{\lambda}$*w. r. t.* means 'with respect to'

Table 2*b***.** Height-gain-target-achievement index, h_C, and mass-management-target-achievement index, μ_C, of Hr. S. at her last (third) checkup

At the 4th *Checkup* (November 21, 2013)	*Measured Height*		*Measured Mass* (*Weight*)	
	cm	*ft-in*	*kg*	*lb-oz*
Measured Values	**126.45**	**4 *ft* 1.78 *in***	**22.53**	**49 *lb* 10.86 *oz***
Recommended by Roadmap 2.6	127.92	4 *ft* 3.17 *in*	24.65 - 26.07	54 *lb* 5.54 *oz* - 57 *lb* 7.91 *oz*
Target-Achievement Index	98.85 %		91.41 % ↓	
Qualitative	h_C under -achieved		μ_C under-achieved (lesser mass outside the normal range)	

pseudo-gain of mass. Puberty rating is explained in Table 4 of Kamal *et al*. (2017*b*). Table 2*b* displays how well the child has responded to the recommendations of height and weight management provided at the time of her second checkup. Table 2*c* provides height and weight management targets prepared on the basis of third checkup.

Table 2*c***.** Month-wise height targets and mass (weight) target ranges for Hr. S.

Reference Height© = 128.76 *cm* • Percentile-of-Reference Height = 36.49P
Estimated-Adult-Reference-*BMI*-based-Optimal-Mass = 62.19 *kg*
Percentile-of-Reference-*BMI*-based-Optimal-Mass = 63.01P

Target Date	*Height Target*		*Range of Mass* (*Weight*) *Target Range*	
	cm	*ft-in*	*kg*	*lb-oz*
November 21, 2013 (reference)	**126.45**	**4 *ft* 1.78 *in***	**22.53**	**49 *lb* 10.86 *oz***
December 21, 2013 (1st month)	127.22	4 *ft* 2.09 *in*	23.18-23.63	51 *lb* 1.74 *oz* - 52 *lb* 1.65 *oz*
January 21, 2014 (2nd month)	127.90	4 *ft* 2.36 *in*	23.83-24.74	52 *lb* 8.89 *oz* - 54 *lb* 8.75 *oz*
February 21, 2014 (3rd month)	128.55	4 *ft* 2.61 *in*	24.48-25.74	53 *lb* 15.49 *oz* - 56 *lb* 2.11 *oz*
March 21, 2014 (4th month)	129.12	4 *ft* 2.84 *in*	25.04-26.09	55 *lb* 3.39 *oz* - 57 *lb* 8.33 *oz*
April 21, 2014 (5th month)	129.74	4 *ft* 3.08 *in*	25.65-27.44	56 *lb* 9.05 *oz* - 60 *lb* 7.97 *oz*
May 21, 2014 (6th month)	130.31	4 *ft* 3.30 *in*	26.22-28.27	57 *lb* 13.08 *oz* - 62 *lb* 5.46 *oz*

©Estimated-Adult-Reference Height is equal to Adult-Mid-Parental (Target) Height (162.975 *cm*) in this particular case

Figure 6 gives height and mass trajectories of Hr. S. during all her checkups, as well as recommendation to steer the

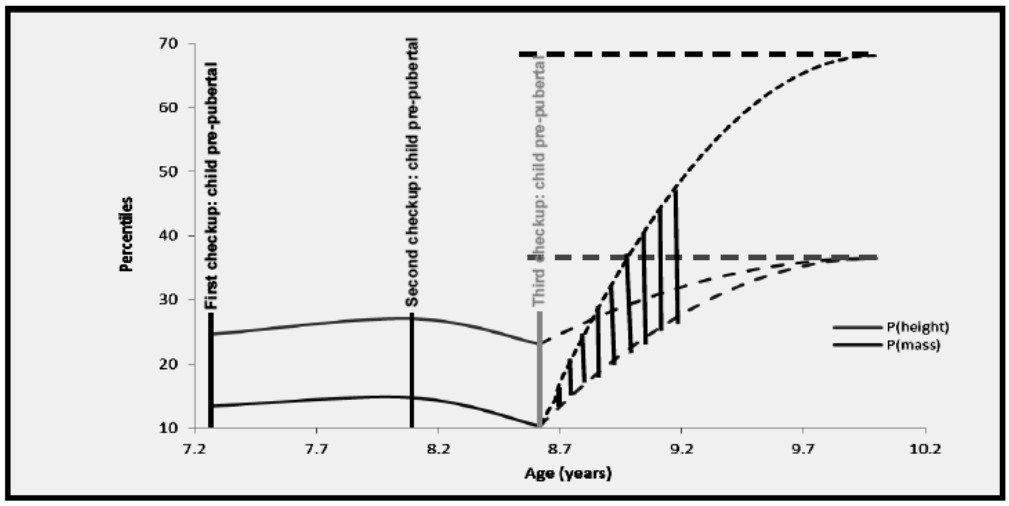

Fig.6. Time evolution of height and mass CDC percentiles of Hr. S. for her three checkups — the age range was 7.26-8.62 *years* (navigational trajectories**:** solid curves), including the desired course-of-action (guidance trajectories**:** green-dashed line for reference percentile, black-dashed line for reference-*BMI*-based-optimal-mass percentile) and recommended intervention (control-action trajectories**:** blue-dashed for height-percentile curve and maroon-shaded for mass-percentile curve) based on Growth-and-Obesity Vector-Roadmap 2.6

Table 2*d*. Time slots (24-*hour* clock), valid for the city of Karachi, Pakistan, for full body[δ] sun-exposure[ε] of Hr. S. during 6-*month* period following her last (third) checkup to obtain the required doses of vitamin D

Date	*Safe Period*[ϕ]	*Intermittent Period*[χ]	*Prohibited Period*	*Intermittent Period*	*Safe Period*
DECEMBER					
01	0700h-0804h	0805h- 0909h	0910h-1532h	1533h-1637h	1638h-1742h
15	0709h-0813h	0814h-0918h	0919h-1535h	1536h-1640h	1641h-1745h
JANUARY					
01	0717h-0820h	0821h-0924h	0925h-1546h	1547h-1650h	1651h-1754h
15	0719h -0823h	0824h-0928h	0929h-1554h	1555h -1659h	1700h-1804h
FEBRUARY					
01	0715h-0821h	0822h-0928h	0929h-1603h	1604h-1710h	1711h-1817h
15	0707h-0815h	0816h-0924h	0925h-1608h	1609h-1717h	1718h-1826h
MARCH					
01	0655h-0811h	0812h-0928h	0929h-1600h	1601h-1717h	1718h-1834h
15	0641h -0753h	0754h-0906h	0907h-1615h	1616h-1728h	1729h-1841h
APRIL					
01	0624h-0738h	0739h-0853h	0854h-1618h	1619h-1733h	1734h-1848h
15	0610h-0726h	0727h-0843h	0844h-1620h	1621h-1737h	1738h-1854h
MAY					
01	0556h-0715h	0716h-0835h	0836h-1622h	1623h-1742h	1743h-1902h
15	0548h-0708h	0709h-0829h	0830h-1627h	1628h-1748h	1749h-1909h

[δ]Hr. S. barefooted, bareheaded, dressed in panties only (all clothing above the waist removed), hair opened up, eyes protected through UV-cutoff glasses, engaged in light exercises/free play — if sitting for drawing, jigsaw puzzles, painting, singing, story-telling/listening, her back should be towards the sun

[ε]10-15-*minute* guarded-graduated sun exposure (Kamal and Khan, 2018)

[ϕ]Safe-exposure duration is when the sun has not reached 18^o after rising or is at an angle less than 18^o before setting; children may be exposed to direct sunlight (suitable for summer months)

[χ]Intermittent-exposure duration is when the sun is at an angle between 18^o and 36^o (end-points included) after rising or between 36^o and 18^o (end-points included) before setting; children may be allowed to play in the shade with brief periods of sun exposure (suitable for winter months); 12-*month* table for Karachi, Sindh, Pakistan is available in Kamal and Khan (2020*a*)

trajectories in the coming months to achieve desired height gain and mass management.

We present in Table 3, computation of build for each of the 3 checkups of Hr. S. using CDC (suitable for population of United States of America), scaled (suitable for other countries, where modeling based on indigenous data is not done to generate modified-scaled percentiles) and modified-scaled percentiles (based on indigenous data of a given country, in our case, Pakistan), in order to see how does a particular choice of percentile affects the results.

Table 3. Build of Hr. S. computed using CDC, scaled and modified-scaled percentiles — sum of percentiles of height and mass inserted in parentheses after assigned build

Age (*years*)	*Build Assignment using*		
	CDC Percentiles	*Scaled Percentiles*	*Modified-Scaled Percentiles*
7.26 (1st checkup)	Small (32.76)	Small (43.85)	Medium (65.72)
8.10 (2nd checkup)	Small (41.82)	Medium (55.29)	Medium (82.17)
8.62 (3rd checkup)	Small (33.38)	Small (44.63)	Medium (68.43)

APPENDIX B: FLOWCHART OF SOFTGROWTH 2.6

SOFTGROWTH 2.6 computes Growth-and-Obesity Scalar- and Vector-Roadmaps 2.6, which include recommendations to achieve height landmarks and manage mass (weight) within the next 6 *months*. Flowchart is given on the next page (Figure 7).

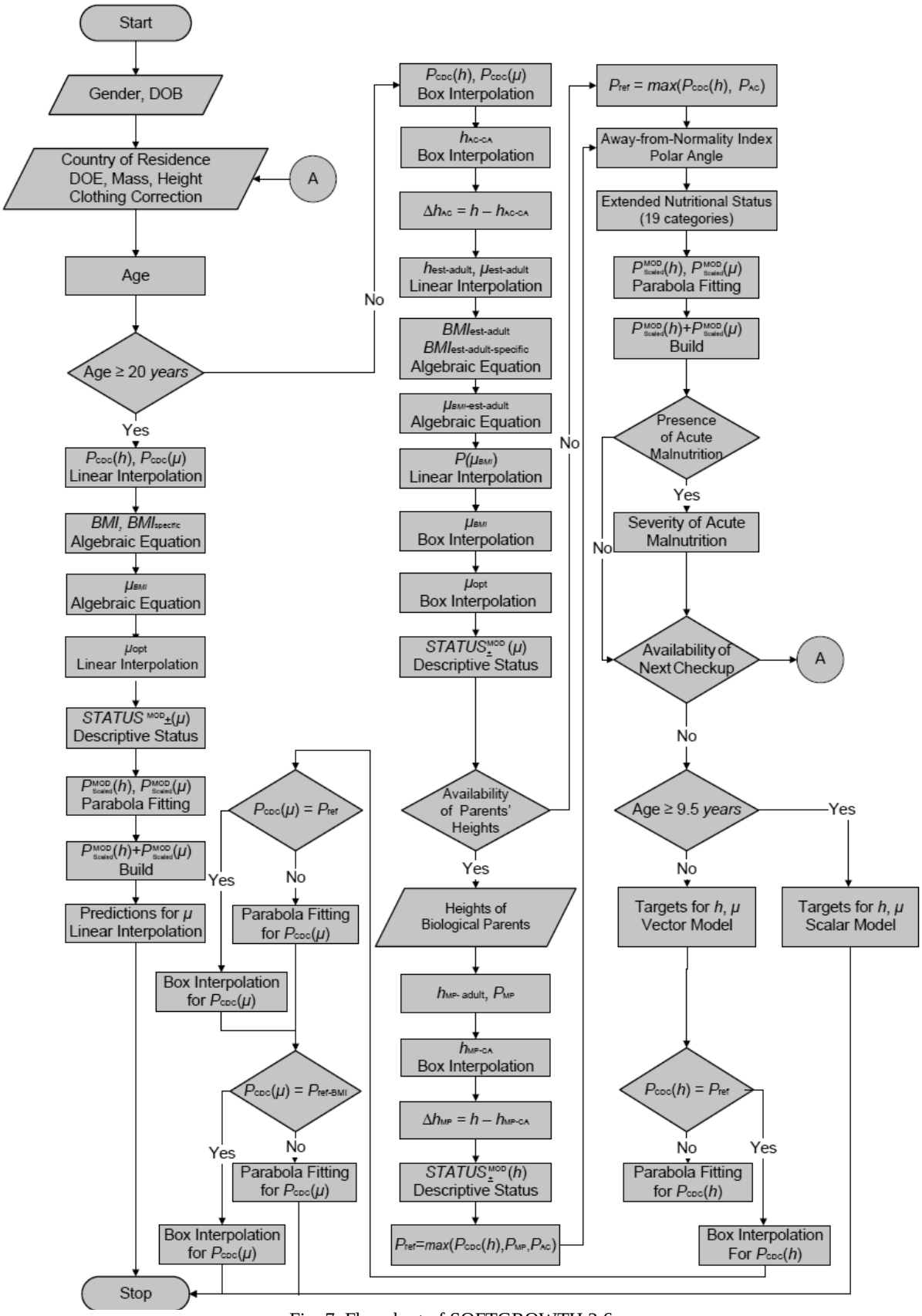

Fig. 7. Flowchart of SOFTGROWTH 2.6

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Additional File 1 — Techniques of Anthropometric Measurements (step-by-step procedures illustrated through labeled photographs): https://www.ngds-ku.org/Papers/J60/Additional_File_1.pdf
Additional File 3 — Method of Constructing Roadmap 2.6: https://www.ngds-ku.org/Papers/J60/Additional_File_3.pdf
Additional File 4 — Lifestyle Adjustment, Diet and Exercise Plans:
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