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PREVALENCE OF ACUTE MALNUTRITION IN CHILDREN OF KARACHI DETERMINED FROM THEIR GROWTH-AND-OBESITY ROAD-MAPS 4.5 - THE TENTH-GENERATION SOLUTION OF CHILDHOOD OBESITY-AND-MALNUTRITION

Syed Arif Kamal*

Founding Project Director, *The NGDS Pilot Project*, *PO Box 8423*, *Karachi 75270*, *Pakistan*; profdrakamal@gmail.com

ABSTRACT

Acute malnutrition is a devastating epidemic affecting some 55 million children globally with yearly mortality of around 3.1 million. This condition is caused by reduction in food consumption, increase of energy expenditure or diseases, which produce sudden weight loss or oedema (fluid retention). Prolonged acute malnutrition may cause stunted growth and reduced educational achievements. One of the leading problems in under-developed world, acute malnutrition may be tackled with medicines, lifestyle adjustment, medical nutrition and immune-system-targeted nutracauticals to reduce costs of care, decrease number of complications, stays in hospitals for lesser number of days and reduction of mortality. In this paper, the author has studied a convenience sample of 1666 children (16 boys and 9 girls were found to be acutely malnourished) and computed their 'severity of acute malnutrition'. The severity of acute malnutrition is categorized as 'mild' — 0-33.33% (9 boys; 8 girls), 'intermediate' — 33.34%-66.66% (4 boys; 1 girl) or 'extreme' — 66.67%-100% (3 boys, zero girls). The case of a cardiac patient is analyzed based on Roadmap 4.5 and compared with the earlier analyses.

Keywords: *BMI*-based-optimal mass • estimated-adult-specific *BMI* • estimated-adult height • height-gain-target-achievement index • height-percentile-based-optimal mass • mass-management-target-achievement index • modified-scaled percentiles

LIST OF ABBREVIATIONS

***BMI*: B**ody-**M**ass **I**ndex • **CDC: C**enters for **D**isease **C**ontrol and Prevention • **NCHS: N**ational **C**enter for **H**ealth **S**tatistics • **NGDS:** The **N**ational **G**rowth and **D**evelopmental **S**tandards for the Pakistani Children • **^{P}: P**ercentile • **SD: S**tandard **D**eviation(s) • **SGPP:** The **S**ibling **G**rowth **P**ilot **P**roject

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

Conversion Factors: 1 *ft* = 12 *in* • 1 *in* = 2.54 *cm* • 1 *kg* = 2.205 *lb* • 1 *lb* = 16 *oz*

INTRODUCTION

Acute malnutrition is a form of under-nutrition, which appears because of decrease in food consumption, increase of energy expenditure or diseases responsible for sudden weight loss or oedema (fluid retention). It is a devastating epidemic. It is estimated that globally some 55 million youngsters under the age of five suffer from cute malnutrition. Every year 3.1 million children expire due to malnutrition. Acute malnutrition can be moderate or severe, and prolonged malnutrition can cause stunted growth, otherwise known as stunting, reduced educational achievements, resulting in the long run poor productivity and economic capacity. Acute malnutrition is one of the leading problems in under-developed world, which may be handled with medicines, lifestyle adjustment, medical nutrition and immune-system-targeted nutracauticals to reduce costs of care, decrease number of complications, stays in hospitals for lesser number of days and reduction of mortality.

In this paper, the author has studied a convenience sample of 1666 children and classified their acute malnutrition as 'mild', 'intermediate' or 'extreme' by computing their 'severity of acute malnutrition', in the process proposing the tenth-generation solution of childhood obesity-and-malnutrition (Growth-and-Obesity Roadmaps 4.5).

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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 • *homepage***:** https://www.ngds-ku.org/kamal • *the NGDS Pilot Project URL***:** https://ngds-ku.org • *SGPP link***:** https://www.ngds-ku.org/ngds_URL/subprojects.htm#SGPP

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

The case of a cardiac patient is analyzed based on Roadmap 4.5 and compared with the earlier analyses.

ACUTE MALNUTRITION IN CHILDREN

Acute malnutrition in children is becoming a much larger problem these days as compared to childhood obesity. Such children are weak and hence become vulnerable to community- and hospital-based bacteremia (Andersen *et al.*, 2022) as well as tuberculosis (Vonasek *et al.*, 2022). Cazes *et al.* (2022) assessed whether integrating severe acute malnutrition and moderate acute malnutrition treatment into a single program, using one nutritional product and decreasing dosage as there is improvement in the condition of youngster, could achieve similar or higher individual efficacy, increase coverage, and minimize costs compared with the existing programs. They concluded that the OptiMA malnutrition treatment protocol was superior to the existing Democratic Republic of the Congo National Protocol in terms of favorable outcomes at 6 months after inclusion. Isanaka *et al.* (2016) discussed use of routine amoxicillin for uncomplicated severe acute malnutrition in children. Mishra *et al.* (2014) described a case-control study conducted in India to identify certain risk factors for severe acute malnutrition in children below 5 years of age, which need to be focused on during health planning and policy making. Mulugeta and Gebregiabher (2022) discussed the situation of children in Tigray, Northern Ethopia, where armed conflict has been raging since November 4, 2020. This has resulted in total blockade of humanitarian aid, destruction of health facilities and displacement of a large portion of population. All of these have resulted in preventable severe and moderate acute malnutrition in children. They call upon the public health and medical communities, in general, and the nutrition community, in particular, to advocate the victims of this man-induced starvation and its long-term consequences.

DEFINITIONS OF ACUTE MALNUTRITION

Collins *et al.* (2006) defined severe acute malnutrition as weight-for-height measurement of 70% or less below the median or 3 SD or more below the mean NCHS reference values. The author has defined acute malnutrition 7-*year* ago as the condition in which both CDC percentiles of height and mass fall below 3^P (Kamal, 2015*a* — equation 3). This definition was modified 2-*year* later in the sense that scaled percentiles were used instead of CDC percentiles and that the sum of scaled percentiles should be less than 6, instead of imposing the condition on scaled percentiles of height and mass, separately, to be below 3^P (Kamal *et al.*, 2017*b* — Table 5 and equation 7). Last year sum of scaled percentiles was replaced by sum of modified-scaled percentiles (Kamal *et al.*, 2021*a*, Additional File 3 — equation AFIII-8). This equation is used for computing severity of acute malnutrition**:**

(1) $$\mathit{Severity\ of\ Acute\ Malnutrition} = 100\left(1 - \frac{P_{\text{Scaled}}^{\text{MOD}}(h) + P_{\text{Scaled}}^{\text{MOD}}(\mu)}{6}\right)\%$$

REGULAR MONITORING OF HEIGHT AND WEIGHT OF CHILDREN

Regular monitoring of height and weight of school-going children (every 6 months) should be mandatory in all civilian (public and private) schools as well as institutions run by the Armed Forces of Pakistan, employing internationally-agreed protocols (Figure 1). The NGDS Team has produced detailed documents for this purpose (Kamal, 2016; Kamal *et al.*, 2021*a*, Additional File 1). With the CDC Growth Charts and Tables extended to include the widest-possible range — 0.01^{P} to 99.99^{P} (Kamal and Jamil, 2014, Additional File 3) and the availability of 4 equations to convert CDC percentiles to modified-scaled percentiles, obtained from data of the Pakistani children (Kamal *et al.*, 2021*a* — equations 6*a*, *b* and 10*a*, *b*), Growth-and-Obesity Roadmaps of all children should be constructed to determine statuses of obesity, wasting, stunting and acute malnutrition (if present).

MODELING OF CHILD GROWTH, OBESITY AND WASTING

It is of utmost importance to model child growth, obesity and wasting in order to be able to devise intervention plans for children through lifestyle adjustment, diet and exercise plans (Kamal, 2022*b*; Kamal and Khan, 2020*a*) and prevent unnecessary growth hormone treatment (Kamal, 2022*a*).

Akram *et al.* (2018) studied the impacts of complex social, environmental and behavioral factors on obesity. Argelich *et al.* (2021) discussed intervention of pediatric teams to combat childhood obesity in the context of STOP Project. Bramante *et al.* (2019) reviewed natural experiments for the prevention and the control of childhood obesity. Brock *et al.* (2019) described a 3-*year*, mixed-methods case study to adapt, implement and evaluate an evidence-based childhood obesity treatment program. Cheng *et al.* (2022) discussed challenges of predicting child obesity using machine learning. Fowler *et al.* (2021*b*) and Wilfley *et al.* (2021) described the MO-CORD (Missouri Childhood Obesity Research Demonstration) Study Protocol, which meant to translate family-based behavioral treatment for childhood obesity into user-friendly digital package as well as its implementation. This package is to be delivered to low-income families through primary-care partnerships. Greydanus *et al.* (2018) elaborated childhood and adolescent obesity concept in the earlier part of this century, including discussion regarding its history, definition, epidemiology, diagnostic perspectives, psychological considerations, musculoskeletal as well as endocrine complications and principles of management. Hossain *et al.* (2019) identified risk factors for overweight and obesity in children and adolescents in Bangladesh. Ickovics *et al.* (2019) discussed implementation of school-based policies to prevent obesity. Kumanyika (2018) described childhood-obesity prevention efforts in 130 communities of United States in the context of the Healthy Communities Study (HCS). The findings suggest that although many of the strategies being implemented work as intended to improve children's behaviors and statuses of weight, there is an indication of lesser reach to children in demographic groups at highest risk of obesity. Kumar and Kelly (2018) reviewed childhood obesity from the perspectives of epidemiology, etiology and co-morbidities to clinical assessment and treatment. Merrotsy *et al.* (2018) conducted a literature review to determine the most effective settings and components for obesity-prevention programs in children. Razi and Nasiri (2022) conducted a qualitative study dealing with the concerns of parents about children's overweight and obesity during COVID-19 pandemic.

The main challenges are (*a*) management of weight according to the projected height within the next 6 *month*s, so that the child does not become wasted based on recommendations according to current height and (*b*) absence of a proper definition of childhood obesity. Professor Claude Marcus, Head, Division of Pediatrics, Karoliska University Hospital, National Childhood Obesity Center, Karoliska Institutet, Sweden, commented on the author's proposed definition of childhood obesity (Kamal, 2017*a*)**:**

> *Thank you very much. We are deeply concerned about how to define obesity and degree of obesity so we can follow effects of treatment over time and association with co-morbidities. The present obesity curves are unreliable and we are now trying to identify new ways to follow obese children over time. Therefore, your paper is welcome to us.*

There have been attempts to model child growth (Kamal *et al.*, 2011) and obesity (Kamal *et al.*, 2018) by different groups including our group — our group started modeling of child growth, obesity and wasting in 1998 and the first results were published during 2002-2004 (Kamal and Firdous, 2002; Kamal *et al.*, 2004). A summary is available in Kamal *et al.* (2015) and Kamal (2017*b*). Below is brief description of attempts to obtain a working definition of childhood obesity.

Definitions of Childhood Obesity

The way to manage childhood obesity is by accepting a universal definition of obesity in children. One should appreciate that obesity manifests, when there appears a difference between input and output of energy. This results in disappearance of the original steady state and formation of a new one at a higher level, with the consequence of excess body-fat storage. Poskitt (1995), on behalf of the European Childhood Obesity Group (ECOG), opined that researchers were worried about a lack of definition of childhood obesity. She presented the concept of relative *BMI* as the index of 50^P of a youngster — *BMI* is obtained by dividing mass of an individual in *kg* by square of height in *m*. In a follow-up paper, Poskitt (2000) observed that the concept of relative *BMI* has been widely accepted despite considerable imprecision in defining obesity. She stated in 2001 that *BMI* can not be considered as offering the 'best' definition, although it might be considered as the most 'useful' and 'practical' one for clinical, epidemiological and population-research purposes (Poskitt, 2001). In reality, childhood obesity cannot be interpreted easily using *BMI* (Keys *et al.*, 1972; Kolimechkov and Petrov, 2020) from the WHO scale for obesity (percentiles need to be employed). Kamal and Jamil (2012) proposed estimated-adult *BMI* to approximate the obesity status of children, when they are fully grown adults. Rolland-Cachera (2011), on behalf of ECOG, defined three main cutoffs of *BMI* distribution status from the age of 5 *years*, constituting four ranges**:** 'thin', 'normal', 'over-weight' and 'obese'. Cole *et al.* (2000) proposed definition of childhood obesity on the basis of pooled-international data. These researchers connected childhood obesity to adult-obesity-cut-off point of *BMI* to be 30 kg/m^2. A detailed discussion of childhood-obesity definitions appears elsewhere (Kamal, 2017*a*).

Indicators of Obesity Status in Children

Indicators of obesity have been summarized elsewhere (Kamal *et al*., 2021*b* — Table 1). These are *BMI* (Keys *et al.*, 1972), relative *BMI* (Poskitt, 1995), height-percentile-based-optimal mass (Kamal *et al.*, 2004; 2011), status**:** pertaining-to-mass (Kamal *et al.*, 2011), estimated-adult *BMI* (Freedman *et al.*, 2001; Kamal and Jamil, 2012), *BMI* ratio (Kamal and Jamil, 2014), algebraic status**:** pertaining-to-mass (Kamal *et al.*, 2015), qualitative status**:** pertaining-to-mass (Kamal *et al.*, 2015), *BMI*-based-optimal mass (Kamal, 2017*a*), modified status**:** pertaining-to-mass (Kamal *et al.*, 2018), descriptive status, pertaining-to-mass (Kamal *et al.*, 2018), fractional status**:** pertaining-to-mass (Kamal *et al.*, 2018), reference-*BMI*-based-optimal mass (Kamal *et al.*, 2020), specific *BMI* (Kamal *et al.*, 2020), estimated-adult-specific *BMI* (Kamal *et al.*, 2020), refined status**:** pertaining-to-mass (Kamal *et al.*, 2021*b*), depictive status**:** pertaining-to-mass (Kamal *et al.*, 2021*b*) and complex status**:** pertaining-to-mass (Kamal *et al.*, 2021*b*). If a child is recommended to lose weight at the end of 6-*month* period, according to applicable Growth-and-Obesity Scalar- or Vector-Roadmap, that child is classified to have *True Obesity*, definition given in Kamal (2017*a*), but the word, explicitly, mentioned in Kamal *et al.* (2017*a*). This should, also, be included as indicator of obesity. One should appreciate that *Instantaneous Obesity* is the condition in which refined status**:** pertaining-to-mass is positive (Kamal *et al.*, 2017*c*).

SOLUTIONS OF CHILDHOOD OBESITY-AND-MALNUTRITION

Fowler *et al.* (2021*a*) reviewed and conducted meta-analysis of current applications of technological solutions for childhood-obesity prevention and treatment. For needs and drawbacks of the first- to the eighth-generation solutions of childhood obesity as well as need of the ninth-generation solution, one should look at Kamal *et al.* (2021*b*). Since all these solutions, also, mathematically compute existence of malnutrition in children (by determining percentiles of height and mass), the author is renaming these solutions as 'solutions of childhood obesity-and-malnutrition'**:**

The First-Generation Solution of Childhood Obesity-and-Malnutrition

Proposed on September 4, 2013 (Kamal *et al.*, 2013), salient features of the first-generation solution may be summarized as**:**

- Upgraded 'Growth-and-Obesity Moving-Profiles' to 'Growth-and-Obesity Roadmaps'
- Monthly recommendations provided to gain height based on reference height computed at the end of 6 *months*
- Monthly recommendations given to manage weight (mass) according to 6-*month* extrapolated reference height

The Second-Generation Solution of Childhood Obesity-and-Malnutrition

Proposed on September 4, 2014 (Kamal *et al.*, 2014*a*) and published as a paper in a peer-reviewed journal on January 1, 2015 (Kamal *et al.*, 2015), salient features of the second-generation solution may be summarized as**:**

- Reference height redefined as the maximum of measured height, current-age-mid-parental height and current-age-army-cut-off height
- Mass-reduction recommendations for parents as well as children not to exceed 10 *kg* during the next 6 *months*, in order to avoid adverse consequences due to rapid loss of weight
- For mothers (currently married or recently divorced/widowed), the recommended suggestion to reduce mass computed by adding 5 *kg* to net mass, to account for possible pregnancy and the resulting fetal mass

The Third-Generation Solution of Childhood Obesity-and-Malnutrition

Proposed on July 1, 2015 (Kamal, 2015*b*), salient features of the third-generation solution may be summarized as**:**

- A youngster instantaneously approached the value of optimal mass when trajectory of extended percentile-of-mass crossed trajectory of extended percentile-of-height
- For the purpose of maintaining optimal mass, not only, the values, but also, the slopes of trajectories of extended percentiles-of-height and -mass to be matched — dynamical-system approach
- Provided an objective criterion for losing or gaining weight (mass) in slightly obese children at the same time giving month-wise recommendations to pick-up height and gain/lose weight (mass)

The Fourth-Generation Solution of Childhood Obesity-and-Malnutrition

Proposed on February 13, 2016 (Kamal *et al.*, 2016*b*) and published as a paper in a peer-reviewed journal on October 1, 2016 (Kamal *et al.*, 2016*a*), salient features of the fourth-generation solution may be summarized as**:**

- 'Growth-and-Obesity Vector-Roadmaps' introduced for children below age 9.5 *years*
- Softer goals of height and weight (mass) management obtained through parabolic curves fitted to height- and mass-percentile trajectories, which originated at age of the most-recent checkup and terminated at the reference age (10 *years*)
- Constructed in such a manner that the desired trajectory tangentially touched the reference trajectory at the age of 10 *years*

The Fifth-Generation Solution of Childhood Obesity-and-Malnutrition

Proposed on January 1, 2017 (Kamal, 2017*a*) and validated in a subsequent work published on April 1, 2017 (Kamal *et al.*, 2017*a*), salient features of the fifth-generation solution may be summarized as**:**

- Put forward logical and mathematical definitions of childhood obesity
- Proposed a method to compute *BMI*-based-optimal mass for adults and children based on the reference value 24 kg/m^2
- Compared *BMI*-based-optimal mass and height-percentile-based-optimal mass; the former does not differentiate between normal and obese youngsters in the context of the Pakistani children

The Sixth-Generation Solution of Childhood Obesity-and-Malnutrition

Proposed on October 1, 2017 (Kamal, 2017*b*), salient features of the sixth-generation solution may be summarized as**:**

- 'Growth-and-Obesity Roadmaps 2.0' gave a range for 6 month-wise targets for management of mass in place of single values
- Accomplished using statistical technique of fitting 2 parabolic curves, both started at the age, when the most recent checkup was performed
- At the age of 10 *years*, one of these curves tangentially met the straight line representing computed reference percentile and the other the straight line representing percentile of *BMI*-based optimal mass

The Seventh-Generation Solution of Childhood Obesity-and-Malnutrition

Proposed on October 1, 2018 (Kamal *et al.*, 2018), salient features of the seventh-generation solution may be summarized as**:**

- 'Growth-and-Obesity Roadmaps 2.1' used modified statuses (pertaining-to-height) and (pertaining-to-mass) instead of the corresponding algebraic statuses as well as descriptive statuses (pertaining-to-height) and (pertaining-to-mass) instead of the corresponding qualitative statuses
- Nutritional-status categories expanded to 10 from the previously used 6 categories
- Fractional status (pertaining-to-height-and-mass) was obtained by creating a complex number from fractional status (pertaining-to-mass) and fractional status (pertaining-to-height), magnitude representing 'away-from-normality index'

The Eighth-Generation Solution of Childhood Obesity-and-Malnutrition

Proposed on January 1, 2020 (Kamal *et al.*, 2020), salient features of the eighth-generation solution may be summarized as**:**

- 'Growth-and-Obesity Roadmaps 2.5 and 3.0' used estimated-adult-reference height to compute percentile of reference-*BMI*-based-optimal mass, employed to compute the ranges of mass management
- Specific *BMI* and specific estimated-adult *BMI* introduced and categories of nutritional status extended from 10 to 19

- Height-gain-target-achievement index and mass-management-target-achievement index computed on the basis of heights and masses measured at the last checkup, the current checkup and the values recommended by Roadmaps 2.5 and 3.0

The Ninth-Generation Solution of Childhood Obesity-and-Malnutrition

Proposed on January 1, 2021 (Kamal *et al.*, 2021*b*), salient features of the ninth-generation solution may be summarized as**:**

- Percentile of reference height in 'Growth-and-Obesity Vector-Roadmaps 4.0' being maximum of 4 percentiles, viz. percentile of measured height, percentile of army-cutoff height, percentile of community-based-median height and percentile of mid-parental height
- Modified statuses (pertaining-to-height) and (pertaining-to-mass) replaced with refined status (pertaining-to-height) and (pertaining-to-mass)
- Categories of nutritional status enhanced to 23 from the previously used 19 categories

THE TENTH-GENERATION SOLUTION OF CHILDHOOD OBESITY-AND-MALNUTRITION — GROWTH-AND-OBESITY ROADMAPS 4.5

In Growth-and-Obesity Roadmaps 4.0, the community-based-median height is considered to be the one corresponding to percentile 40^P based on an earlier suggestion (Kamal *et al.*, 2015). This was mapped to CDC percentile 50^P to construct equations for scaled percentiles (Kamal *et al.*, 2017*b*). There is a need to determine the Pakistani-community-based-median-height percentiles and used in roadmaps. Such percentiles have, already, been worked out based on indigenously collected data of 1666 children (details in next section). Detailed method of construction of 4 equations for modified-scaled percentiles appears elsewhere (Kamal *et al.*, 2021*a*).

The Pakistani-community-based-median-height percentiles are used in place of percentile 40^P — 34.85247886^P for females and 43.21272955^P for males (Kamal *et al.*, 2021*a* — Table 6). Rest of the procedure is identical to the one used for constructing Roadmaps 4.0 (Kamal *et al.*, 2021*b*, Additional File 4). Growth-and-Obesity Vector-Roadmap 4.5 of a child suffering from cardiac problems is included in appendix. Color-coding used in Roadmap 4.5 is explained in Additional File 1. Method of construction is given in Additional File 2.

In the next step, Growth-and-Obesity Roadmaps 5.0 should be constructed to include children of still-growing parents in the format of Growth-and-Obesity Roadmaps 3.0 (Kamal *et al.*, 2020).

PREVALENCE OF ACUTE MALNUTRITION IN CHILDREN OF KARACHI

Prevalence (or prevalence rate) is the proportion of people in a population (expressed as percentage), who are suffering from acute malnutrition at a specified point in time, or over a specified period of time. Mathematically

$$\text{(2)} \qquad Prevalence = 100\,\frac{n(\nu)}{n(\Sigma)}\,\%$$

where $n(\nu)$ represents total number of all new and pre-existing cases during a certain time period, whereas $n(\Sigma)$ represents population during the same time period. The numerator, not only, includes new cases, but also, old cases (children, who remained acutely malnourished at a certain point in time or during a certain period of time). A case is counted in prevalence until death or recovery time. This point makes prevalence different from *incidence*, which includes only new cases, $n(\mu)$, in the numerator.

$$\text{(3)} \qquad Incidence = 100\,\frac{n(\mu)}{n(\Sigma)}\,\%$$

Study Protocols

As per directives of Governor Sindh/Chancellor, University of Karachi, a team from University of Karachi, led by the author, took up the assignment to establish National Growth and Developmental Standards (NGDS) for the Pakistani Children in 1998 by collecting height and weight data in 3 institutions administered by the Armed Forces of Pakistan and later including (in 2011) a civilian school 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 (Kamal *et al.*, 2016*a*, Additional File 1), employing 'Opt-in policy' for participation, requiring parents to complete and sign 'Informed Consent Form'. Checkups were performed giving due consideration to comfort, confidentiality, dignity, privacy and safety of students. Students' data (demographic and clinical) were entered in a structured form. Name, birth date, gender, education and occupation of parents as well as siblings'

Table 1. Descriptive statistics — qualitative and quantitative

Data Collected during *1998-2016*	*Females*	*Males*
Total Number — 1666 (100%)	1163 (69.81%)	503 (30.19%)
Age		
Mean ± Standard Deviation (*years*)	8.51 ± 1.85	6.21 ± 1.70
Median (*years*)	8.64	6.27
Mode (*years*)	8.27	6.68
Range (*years*)	5.01-14.63	3.20-12.07

details were included in the demographic data. Those children requiring extra attention were called in Growth-and-Imaging Laboratory along with their parents and other siblings as part of SGPP.

Subjects and Methods

Heights and weights of students were measured during 1998-2016 as per laid-down procedures (Kamal, 2016; Kamal *et al.*, 2021*a*, Additional File 1). Descriptive statistics (qualitative and quantitative) are given in Table 1. CDC percentiles of height and mass were computed from height and mass of a child using the techniques of box interpolation (Kamal *et al.*, 2011). These percentiles were used to compute severity of acute malnutrition of the Pakistani children till 2016. From 2017 to 2020, scaled percentiles were employed, which were generated by mapping CDC percentile 40^{P} to scaled percentile 50^{P} for both height and mass of a boy or a girl (Kamal *et al.*, 2017*b*). Since 2021, modified-scaled percentiles are being utilized, which are generated by mapping median CDC height (mass) percentile of a sample of boys (girls) to corresponding modified-scaled percentile 50^{P} (Kamal *et al.*, 2021*a*), the medians determined from the sample of 1666 children appear in Table 2. CDC percentiles to modified-scaled percentiles are converted using equations given elsewhere (Kamal *et al.*, 2021*a* — equations 6*a*, *b* and 10*a*, *b*).

Table 2. Median of CDC percentiles mapped to modified-scaled percentiles 50^{P}

Median	*Females*	*Males*
CDC Percentile-of-Height	34.85247886^{P}	43.21272955^{P}
CDC Percentile-of-Mass	19.92558247^{P}	22.99109832^{P}

Data Analysis

Severity of acute malnutrition is computed using equation (1) and is classified as 'mild', 'intermediate' and 'extreme' (Table 3). The percentage entered in parentheses is obtained by multiplying number of cases with 100 and dividing by the respective sample size (female, male or total). For example, the percentage of females suffering from 'mild' form of acute malnutrition is $\frac{(08)(100)}{1163} = 0.6879\,\%$. The prevalence of acute malnutrition is computed as

$$Prevalence = 100\frac{n(\nu)}{n(\Sigma)}\,\% = 100\left(\frac{17+5+3}{1666}\right)\% = 0.9004\,\% \tag{4}$$

RESULTS

Out of 503 boys and 1163 girls measured, acute malnutrition was discovered in 16 boys (3.1809% of the total population) and 9 girls (1.5478%). Among 1666 children examined, 25 (1.5006%) were found to be acutely mal-nourished. A breakdown into as 'mild', 'intermediate' and 'extreme' is available in Table 3.

Table 3. Acute malnutrition in a sample of children hailing from all provinces of Pakistan

'Severity of Acute Malnutrition' / *Sample size*	*Number of children suffering from acute malnutrition*		
	Mild (0-33.33%)	*Intermediate* (33.34%-66.66%)	*Extreme* (66.67%-100%)
Females ($n = 1163$)	08 (0.6879%)	01 (0.0860%)	zero (0)
Males ($n = 503$)	09 (1.7893%)	04 (0.7952%)	03 (0.5964%)
Total ($n = 1666$)	17 (1.0204%)	05 (0.3001%)	03 (0.1801%)

DISCUSSION

Build distribution of the same sample has been determined earlier (Kamal *et al.*, 2021*c*). Those children suffering from acute malnutrition must have small build by definition. Although, a total of 1.5% children were found to be acutely malnourished, it is to be borne in mind that these children are from well-to-do families. Children of the army personnel as well as the educated-middle-class families were studied because of the way this convenience sample was selected. The participating schools were Army Public School, 'O' Levels, Bahria College, NORE I and Fazaia Degree College, PAF Base 'Faisal' all located in Karachi, catering to children of the servicemen from all over the country belonging to the Armed Forces of Pakistan as well as a civilian school, Beacon Light Academy, Karachi, grooming children of the educated-middle class. If a similar study is to be conducted among impoverished groups of children, much higher percentage of acute malnutrition is expected.

RECOMMENDATIONS

Participation in sport through regular academies (Kamal and Khan, 2020*b*) and summer camps (Kamal and Khan, 2021) should improve the general health of children and reduce prevalence of acute malnutrition. In addition, screen time of children (smart phones, laptops, TV) should be reduced and they should be encouraged to spend more time outdoors so that they get a required daily dose of vitamin D (Kamal and Khan, 2018). A balanced diet plan for the acutely malnourished children is of utmost importance to improve their quality of life (Kamal and Khan, 2020*a*).

CONCLUSION

In this paper the author has proposed classification of 'severity of acute malnutrition' (a number between zero and 100%) in terms of mild (less than 33.33%), intermediate (33.34%-66.66%) and extreme (more than 66.67%). A sample of 1666 children has been analyzed to determine the distribution in terms of these categories (gender-wise and cumulative). These tools should be helpful in surveillance of acute malnutrition among different socio-economic groups in Pakistan as well as among children, who are not attending school and involved in child labor. Since computation of severity of acute malnutrition involves percentiles of height and mass based on data of local population, equations for locally scaled percentiles need to be determined from indigenous data of the other countries, where this model is to be applied. Realizing the importance of acute malnutrition in children alongside childhood obesity, wasting and stunting, 'solutions of childhood obesity' are renamed as 'solutions of childhood obesity-and-malnutrition', the tenth-generation solution proposed in this paper.

With balanced diet, ample opportunities to play outdoors and relaxed lifestyle for children and their parents, the author hopes that the next generation would be able to concentrate on acquiring education and skills needed to cope with the challenges of the third millennium.

KEY POINTS

- Acute malnutrition in childhood is a condition, which is as important as childhood obesity in the long-term well being of the population.
- There is a dire need to quantify severity of acute malnutrition to be able to understand health risks in a child.
- Severity of acute malnutrition was expressed in terms of modified-scaled percentiles generated by mapping medians of CDC percentiles of height and mass determined from the data of 1666 Pakistani children to modified-scaled percentiles 50^{P}, generating 4 equations, which allowed conversion of CDC percentiles to modified-scaled percentiles.
- Growth-and-Obesity Vector-Roadmap 4.0 was upgraded to Growth-and-Obesity Vector-Roadmap 4.5 employing modified-scaled percentiles and case of a pediatric-cardiac patient, exhibiting acute malnutrition, was analyzed using Roadmap 4.5.
- A sample of 1666 Pakistani children (503 boys; 1163 girls) was processed and 25 cases of acute malnutrition found using modified-scaled percentiles, out of which 3 fell into 'extreme' category, 5 'intermediate' and 17 'mild' — prevalence of acute malnutrition came out to be 1.5006%.

HUMAN-RIGHT PROTOCOLS

Informed consent was obtained from parent(s) of each participating student for the school-based study (the NGDS Pilot Project) as well as parents for the family-centered study (Sibling Growth Pilot Project — SGPP). Details of the informed-consent process (as well as compliance with the ethical and the human-right protocols) are given elsewhere (Kamal *et al.*, 2017*a*, Additional File 1). Forms are available on website of the NGDS Pilot Project**:**

Informed Consent Form**:** https://www.ngds-ku.org/ngds_folder/Protocols/NGDS_Form.pdf

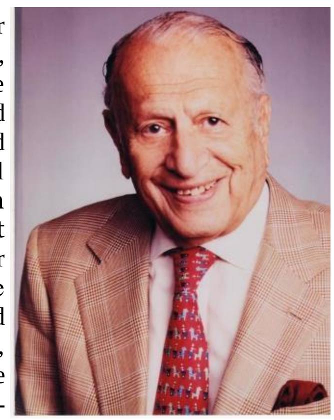
SGPP Participation Form**:** https://www.ngds-ku.org/SGPP/SGPP_Form.pdf

To safeguard privacy of G. R's family, the photographs, included in G. R.'s Growth-and-Obesity Roadmap, do not show the actual child, whose profile is presented. These photographs are selected from the set of children, enrolled in Growth-and-Obesity-Obesity-Monitoring Program conducted at Growth-and-Imaging Laboratory. In addition, family label (R.) and initials of child (G. R.) are different from first letters in actual names (according to the NGDS Pilot Project's confidentiality standards). Same holds for the case number appearing in this paper and the additional resources. Further, in place of scanned signatures, initials are given, again, to protect confidentiality.

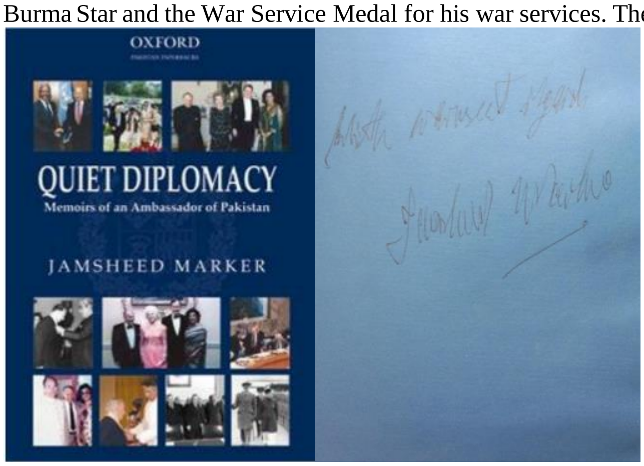
CONFLICT OF INTEREST

The authors declare no conflict of interest. This work contains no libelous or unlawful statements and does not infringe or violate the publicity or the privacy rights of any third party.

DEDICATION



The author would like to dedicate this paper to the loving memory of Ambassador **Jamsheed Kekobad Ardeshir Marker** (Friday, November 24, 1922, Hyderabad Deccan, British India – Tuesday, June 21, 2018, Karachi, Sindh, Pakistan). His family was in the shipping business. He attended Doon Boarding School in Dehradun, British India and Forman Christian College in Lahore, where he studied economics and graduated as a gold medallist with an honors degree. During World War II, he was an officer in the Royal Indian Naval Volunteer Reserve. Markar served as a diplomat representing Pakistan for an illustrious 30-year-long career in more countries than any other diplomat including France, Ghana, Japan, Switzerland and United States. Kofi Annan, after Marker's retirement, appointed him as UN Secretary General's Personal Representative for East Timor. Ambassador Marker afterwards taught international relations at Eckerd College in Florida, United States. He was able to communicate in English, French, German, Gujarati (his native), Russian and Urdu. He was awarded the 1939/45 Star, the Burma Star and the War Service Medal for his war services. The civil awards include Hilal-é-Imtiaz and Sitara-é-Quaid-é-Azam from Government of Pakistan, the Madarski Konnik from Republic of Bulgaria, the Grand Officier de l'Ordre de Mérite from Republic of France and the Grand Cross of the Order of San Carlos from Republic of Columbia. The author met him during the Pakistan Academy of Sciences Karachi Chapter Program; in which Mr. Marker was the Guest Diplomat (the author was, himself, a Guest Scientist in a similar program on Thursday, November 4, 2010). The veteran diplomat wrote "With Warmest Regards" on the personal copy of *Quiet Diplomacy***:** *Memoirs of an Ambassador of Pakistan*, owned by the author (image on left). Other publications of Mr. Marker are *East Timor***:** *a Memoir of the Negotiation for Independence* and *Cover Point***:** *Impressions of Leadership in Pakistan*.



ADDITIONAL RESOURCES

Additional File 1 https://www.ngds-ku.org/Papers/J67/Additional_File_1.pdf explains color-coding used in Growth-and-Obesity Roadmaps 4.5 — Growth-and-Obesity Scalar-Roadmap 4.5 and Growth-and-Obesity Vector-Roadmap 4.5.

Additional File 2 https://www.ngds-ku.org/Papers/J67/Additional_File_2.pdf elaborates methods of construction of Roadmaps 4.5 — Growth-and-Obesity Scalar-Roadmap 4.5 and Growth-and-Obesity Vector-Roadmap 4.5.

Additional File 3 https://www.ngds-ku.org/Papers/J67/Additional_File_3.pdf includes height-gain-target-achievement index and mass-management target-achievement index as well as month-wise height targets and mass target ranges for the next 6 *months* for G. R.

G. R. (NGDS-BLA-2010-4660/F; SGPP-KHI-20110412-02/02)
*G. R.***:** Female, 6+ at the first checkup, biological child, second of 3 children (an older sister and a younger brother). She was observed in Growth-and-Imaging Laboratory during the period 2011-2013 (age range 6.47-8.53 *years*).
*Family History***:** father**:** blood group B+, born December 21, 1971; mother**:** blood group O+, born November 17, 1975; maternal grandfather had cardiac problems
*Pregnancy, Delivery and Neonatal***:** After a normal pregnancy of 9 *months*, she was born (normal delivery) on November 2, 2004 (birth weight 2.5 *kg*; blood group O+); breastfeeding discontinued after 6 *months* due to problems in breathing
*Sleep Pattern and Diet Habits***:** Daily routine consisted of 9-*hour* sleep; 3 meals (relaxed) and 1 snack (relaxed)
*Academics and Social Interaction***:** Good both academically and in social interactions; lacked independence and got tired, easily
*Sports and Co-Curricular Activities***:** Did not participate in co-curricular activities and sports
*Cardiac History***:** Had cardiac surgery when 5-*day* old; when 5-*year* old, she was diagnosed to have Pulmonary Atresia with Ventricular Septal Defect (VSD); had corrective surgery for closure of VSD and formation of right ventricle to pulmonary artery continuity by using a valved conduit; at the age of 7 *years*, she received another surgery
*Physical Examination***:** All of her checkups were conducted with the child barefoot and completely undressed except underwear; relaxed and coöperative during every checkup; right-handed, hair rough, nails white and teeth yellow; lips black at 2nd checkup and blue at 3rd checkup (indicative of cyanosis); normal heart sounds at four locations at 1st checkup, heart beat not OK at 2nd and 3rd checkups, thumping heart but normal sounds at 4th checkup; surgical scar seen at 1st checkup, which showed healing at 2nd and 3rd checkups; a new surgical scar on chest observed at 4th checkup

Fig. 2. History and physical examination of G. R. — posture and moiré photographs of G. R. appear elsewhere (Kamal, 2015*a* — Figures 5*a*-*f*)

APPENDIX: GROWTH-AND-OBESITY VECTOR-ROADMAP 4.5 OF A CARDIAC PATIENT, G. R.

The case of G. R. (worked out below using Growth-and-Obesity Vector-Roadmap 4.5, Tables 4*a*-*d*, height-gain-target-achievement index and mass-management target-achievement index as well as month-wise height targets and mass-target ranges for the next 6 *months* given in Additional File 3 — history and physical examination summary of G. R. is given in Figure 2 and comparison of 'severity of acute malnutrition' determined using CDC percentiles, scaled percentiles and modified-scaled percentiles appears in Figure 3) was first discussed 7-*year* ago (Kamal, 2015*a* — Growth-and-Obesity Scalar-Roadmap of G. R., Tables 4, 5*a*, *b*; posture and moiré photographs of G. R., Figures 5*a*-*f*; trajectories of CDC percentiles of height and mass, Figure 6). Growth-and-Obesity Vector-Roadmap 1.0 of G. R. was constructed after 2 years of the first publication (Kamal *et al.*, 2017*b*, Additional File 3 — Table AFIII-1) as well as Growth-and-Obesity Vector-Roadmap 4.0 was generated last year (Kamal *et al.*, 2021*b*, Additional File 4 — Tables AFIV-2*a*, *b*). Extended Growth Charts and Tables were needed to determine CDC percentiles of G. R. as they all were below 3^{P} (Kamal and Jamil, 2014, Additional File 3).

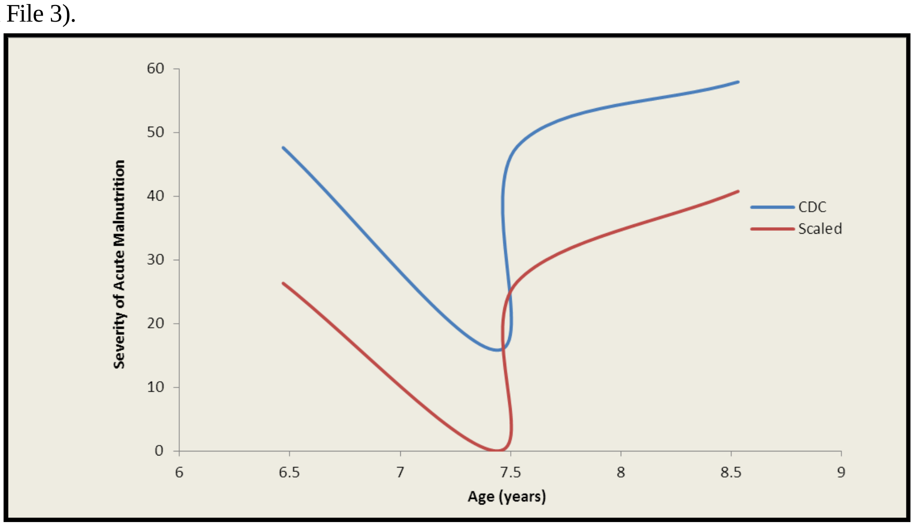


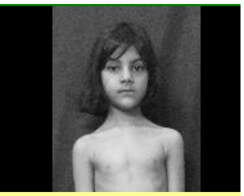
Fig. 3. Comparison of 'Severity of Acute Malnutrition' of G.R. determined on the basis of CDC and scaled percentiles during the age range 6.47-8.53 *years* — for the purpose of drawing graph based on scaled percentiles, 'Severity of Acute Malnutrition' is taken as zero at the age 7.44 *years* (acute malnutrition not present, actually), acute malnutrition absent during all of her checkups, when modified scaled percentiles were used

Table 4*a*. Growth-and-Obesity Vector-Roadmap 4.5 of G. R. — 1st and 2nd checkups

Gender: Female ♀ • *Date of Birth* (*year-month-day*): 2004-11-02

Adult-Army-Cut-off Height[ν]: ♀ 157.48 *cm* (19.36^{P}) • *Adult-Median Height*[φ]: ♀ 160.69 *cm* (34.85^{P})

Father's Height: ♂ 167.90 *cm* • *Mother's Height*: ♀ 153.02 *cm* • *Target Height*[⊕]: 153.96 *cm* (7.77^{P})

Checkup	*1st*	*2nd*
Photograph		
Scanned Signatures	*GR*	*GR*
Class	KG	I
Date of Checkup (*year-month-day*)	2011-04-21	2012-04-11
Time of checkup (24-*hour* clock)	0900h	0945h
Age (*year-month-day*)	06-05-19	07-05-09
Age (*decimal years*)	6.47	7.44
Puberty Rating[µ]	Tanner 1	Tanner 1
Height (*cm*) ⇐	107.60	**113.48**
Height (*ft-in*)	3 *ft* 6.36 *in*	3 *ft* 8.68 *in*
CDC Percentile-of-Height ⇔	2.58^{P}	**2.69^{P}**
Modified-Scaled Percentile-of-Height	4.26^{P}	4.44^{P}
Current-Age-Army-Cut-off Height (*cm*) ⇐	113.25	119.27
Δ Height *with respect to* Current-Age-Army-Cut-off Height (*cm*)	–5.65	–5.79
Current-Age-Mid-Parental Height (*cm*) ⇐	110.54	116.38
Δ Height *with respect to* Current-Age-Mid-Parental Height (*cm*)	–2.94	–2.90
Estimated-Adult Height (*cm*)	150.20	150.44
Estimated-Adult Height (*ft–in*)	**4 *ft* 11.13 *in***	**4 *ft* 11.23 *in***
Refined Status (pertaining-to-height)	–2.66%	–2.49%
Depictive Status (pertaining-to-height)	**1st-Degree Stunted**	**1st-Degree Stunted**
Net Mass (*kg*) ⇒	13.30	17.65
Net Weight (*lb-oz*)	29 *lb* 5.22 *oz*	38 *lb* 14.69 *oz*
CDC Percentile-of-Net-Mass ⇔	0.56^{P}	2.36^{P}
Modified-Scaled Percentile-of-Net-Mass	3.41^{P}	11.64^{P}
Percentile-of-Reference-*BMI*-based-Optimal-Mass ⇔	62.28^{P}	62.28^{P}
Reference-*BMI*-based-Optimal-Mass (*kg*) ⇒	22.62	25.46
Δ Mass *with respect to* Reference-*BMI*-based-Optimal-Mass (*kg*)	–9.02	–7.81
Height-Percentile-based-Optimal Mass (*kg*) ⇒	16.30	18.06
Δ Mass *with respect to* Height-Percentile-based-Optimal-Mass (*kg*)	–3.00	–0.41
Estimated-Adult Mass (*kg*)	35.06	42.97
Estimated-Adult Weight (*lb–oz*)	77 *lb* 4.91 *oz*	94 *lb* 11.98 *oz*
Refined Status (pertaining-to-mass)	–18.38%	–2.27%
Depictive Status (pertaining-to-mass)	**2nd-Degree Wasted**	**1st-Degree Wasted**
Away-from-Normality Index	0.1857	0.0337
Polar Angle (*degrees*)	188.22^{o}	227.68^{o}
Enhanced Nutritional Status	**W-UN**	**S-UN**
Estimated-Adult *BMI* (*kg*/*m*^{2})	15.37	18.99
Estimated-Adult-Specific *BMI*	0.6405	0.7911
Build	**Small**	**Small**

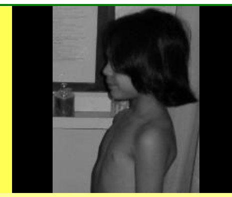
[ν]Adult-army-cut-off height for the Pakistani females, 157.48 *cm*, which converts to 5 *ft* 2 *in* (Kamal *et al.*, 2017*c* —Table 3) corresponding to army-cut-off-percentile (CDC) 19.35609323536863…^{P} (Kamal and Naz, 2021 — Figure 3)

[φ]Adult-median height for the Pakistani females, 160.688 *cm*, which converts to 5 *ft* 3.26 *in*, obtained from indigenous data of 1163 girls corresponding to percentile: CDC 34.85247886...^{P} ⇒ modified-scaled 50^{P} (Kamal *et al.*, 2021*a* — Table 6)

[⊕]Target (Adult-mid-parental) height computed on the basis of formulae given in Tanner *et al.* (1970)

[µ]Tanner 1 indicates that the child is prepubertal (Kamal *et al.*, 2017*b* — Table 4)

Table 4*b*. Growth-and-Obesity Vector-Roadmap 4.5 of G. R. — 3^{rd} and 4^{th} checkups

Checkup	3^{rd}	4^{th}
Photograph		
Scanned Signatures	*GR*	*GR*
Class	I	II
Date of Checkup (*year-month-day*)	2012-05-13	2013-05-16
Time of checkup (24-*hour* clock)	1007h	0845h
Age (*year-month-day*)	07-06-11	08-06-14
Age (*decimal years*)	7.53	8.53
Puberty Rating	Tanner 1	Tanner 1
Height (*cm*) ⇐	**113.72**	**117.46**
Height (*ft-in*)	3 *ft* 8.77 *in*	3 *ft* 10.24 *in*
CDC Percentile-of-Height ⇔	**2.58^{P}**	**2.01^{P}**
Modified-Scaled Percentile-of-Height	4.26^{P}	3.32^{P}
Current-Age-Army-Cut-off Height (*cm*) ⇐	119.79	125.17
Δ Height *with respect to* Current-Age-Army-Cut-off Height (*cm*)	–6.07	–7.71
Current-Age-Mid-Parental Height (*cm*) ⇐	116.88	122.07
Δ Height *with respect to* Current-Age-Mid-Parental Height (*cm*)	–3.16	–4.61
Estimated-Adult Height (*cm*)	150.19	148.94
Estimated-Adult Height (*ft–in*)	**4 *ft* 11.13 *in***	**4 *ft* 10.64 *in***
Refined Status (pertaining-to-height)	–2.70%	–3.77%
Depictive Status (pertaining-to-height)	**1st-Degree Stunted**	**1st-Degree Stunted**
Net Mass (*kg*) ⇒	**14.51**	**15.57**
Net Weight (*lb-oz*)	31 *lb* 15.91 *oz*	34 *lb* 5.31 *oz*
CDC Percentile-of-Net-Mass ⇔	**0.55^{P}**	**0.51^{P}**
Modified-Scaled Percentile-of-Net-Mass	3.38^{P}	3.14^{P}
Percentile-of-Reference-*BMI*-based-Optimal-Mass ⇔	62.28^{P}	62.28^{P}
Reference-*BMI*-based-Optimal-Mass (*kg*) ⇒	25.74	29.21
Δ Mass *with respect to* Reference-*BMI*-based-Optimal-Mass (*kg*)	–11.23	–13.64
Height-Percentile-based-Optimal Mass (*kg*) ⇒	18.07	19.07
Δ Mass *with respect to* Height-Percentile-based-Optimal-Mass (*kg*)	–3.56	–3.50
Estimated-Adult Mass (*kg*)	35.02	34.24
Estimated-Adult Weight (*lb–oz*)	77 *lb* 3.51 *oz*	75 *lb* 8.06 *oz*
Refined Status (pertaining-to-mass)	–19.69%	–18.37%
Depictive Status (pertaining-to-mass)	**2nd-Degree Wasted**	**2nd-Degree Wasted**
Away-from-Normality Index	0.1988	0.1876
Polar Angle (*degrees*)	187.81^{o}	191.61^{o}
Enhanced Nutritional Status	**W-UN**	**W-UN**
Estimated-Adult *BMI* (kg/m^2)	15.35	15.44
Estimated-Adult-Specific *BMI*	0.6397	0.6432
Build	**Small**	**Small**

On examination of Tables 4*a*, *b*, one notes that G. R. exhibits **pseudo-gain of height** between 2^{nd} and 3^{rd} checkup (height pick-up from **113.48 *cm*** to **113.72 *cm***, CDC percentile-of-height dropping from **2.69^{P}** to **2.58^{P}**) as well as between 3^{rd} and 4^{th} checkup (height pick-up from **113.72 *cm*** to **117.46 *cm***, CDC percentile-of-height dropping from **2.58^{P}** to

Table 4*c*. Instantaneous and true obesity/wasting as well as instantaneous and true tallness/stunting during each checkup of G. R.

Checkup	*1st*	*2nd*	*3rd*	*4th*
Instantaneous Tallness	Absent	Absent	Absent	Absent
True Tallness	Absent	Absent	Absent	Absent
Instantaneous Stunting	**Present**	**Present**	**Present**	**Present**
True Stunting	**Present**	**Present**	**Present**	**Present**
Instantaneous Obesity	Absent	Absent	Absent	Absent
True Obesity	Absent	Absent	Absent	Absent
Instantaneous Wasting	**Present**	**Present**	**Present**	**Present**
True Wasting	**Present**	**Present**	**Present**	**Present**
True Over-Nutrition	Absent	Absent	Absent	Absent
True Energy-Channelization I	Absent	Absent	Absent	Absent
True Under-Nutrition	**Present**	**Present**	**Present**	**Present**
Acute Malnutrition	Absent	Absent	Absent	Absent
True Energy-Channelization II	Absent	Absent	Absent	Absent

4.96$^{\mathbf{P}}$). Similarly, G. R. exhibits **pseudo-gain of mass** between 3rd and 4th checkup (mass put-on from **14.51** ***kg*** to **15.57** ***kg***, CDC percentile-of-mass dropping from **0.55**$^{\mathbf{P}}$ to **0.51**$^{\mathbf{P}}$). The phenomenon of pseudo-gain of height (mass) was put forward in Kamal *et al.* (2014*b*). Pseudo-gain of height is present when a drop in CDC percentile-of-height accompanies height gain for two consecutive checkups, with a similar definition for pseudo-gain of mass.

Table 4*c* lists instantaneous and true obesity/wasting as well as instantaneous and true tallness/stunting during each checkup of G. R. True tallness/stunting and true obesity/wasting were explained in Kamal *et al.* (2021*b*). Table 4*d* provides time slots for safe sun-exposure of G. R. during the next half-a-year after the last checkup.

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Table 4*d*. Time slots, valid for the city of Karachi, Pakistan, for full body[δ] sun-exposure[ε] of G. R. during the 6-*month* period following her last (fourth) checkup to obtain the required doses of vitamin D

Date	*Safe Period*[ϕ] *(a. m. – a. m.)*	*Intermittent Period*[χ] *(a. m. – a. m.)*	*Prohibited Period (a. m.- p. m.)*	*Intermittent Period (p. m. – p. m.)*	*Safe Period (p. m. – p. m.)*
JUNE					
01	5: 42 - 7: 06	7: 07 - 8: 31	8: 32 - 4: 17	4: 18 - 5: 52	5: 53 - 7: 17
15	5: 41 - 7: 03	7: 04 - 8: 26	8: 27 - 4: 37	4: 38 - 6: 00	6: 01 - 7: 23
JULY					
01	5: 45 - 7: 07	7: 08 - 8: 30	8: 31 - 4: 40	4: 41 - 6: 03	6: 04 - 7: 26
15	5: 51 - 7: 12	7: 13 - 8: 34	8: 35 - 4: 41	4: 42 - 6: 03	6: 04 - 7: 25
AUGUST					
01	5: 59 - 7: 19	7: 20 - 8: 40	8: 41 - 4: 35	4: 36 - 5: 56	5: 57 - 7: 17
15	6: 06 - 7: 24	7: 25 - 8: 43	8: 44 - 4: 29	4: 30 - 5: 48	5: 49 - 7: 07
SEPTEMBER					
01	6: 12 - 7: 28	7: 29 - 8: 45	8: 46 - 4: 18	4: 19 - 5: 35	5: 36 - 6: 52
15	6: 18 - 7: 32	7: 33 - 8: 47	8: 48 - 4: 07	4: 08 - 5: 22	5: 23 - 6: 37
OCTOBER					
01	6: 24 - 7: 36	7: 37 - 8: 49	8: 50 - 4: 54	4: 55 - 5: 07	5: 08 - 6: 20
15	6: 29 - 7: 39	7: 40 - 8: 50	8: 51 - 3: 44	3: 45 - 4: 55	4: 56 - 6: 06
NOVEMBER					
01	6: 39 - 7: 46	7: 47 - 8: 54	8: 55 - 3: 36	3: 37 - 4: 44	4: 45 - 5: 52
15	6: 49 - 7: 55	7: 56 - 9: 02	9: 03 - 3: 30	3: 31 - 4: 37	4: 38 - 5: 44

[δ]G. R. barefooted, bareheaded, dressed in panties only (all clothing above the waist removed), hair opened up, eyes protected through UV-cut-off 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*)

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