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Percentiles of Height and Mass Scaled for the Pakistani Population: Application to Determine Build of a Gymnast

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Abstract
There is a need for scaling of percentiles, based on mathematical-statistical tools, till charts and tables become available, generated through reliable-indigenously-collected data. Based on height and mass data of 1666 children, collected from all over Pakistan during 1998-2016, modified-scaled percentiles are generated. Parabolic curves are fitted to obtain 2 equations by mapping medians of height-data-CDC percentiles to modified-scaled percentile (50^P), which come out to 43.21^P (CDC — Centers for Disease Control and Prevention) for boys and 34.85^P (CDC) for girls. Circles are fitted to derive 2 equations by mapping medians of mass-data-CDC percentiles to modified-scaled percentile (50^P), which come out to 22.99^P (CDC) for boys and 19.93^P (CDC) for girls. The method is general and could be applied to populations of other countries, like, Turkey, provided a large data sample (of heights and masses) is available. To illustrate the method, builds of a gymnast are determined based on modified-scaled percentiles.

Keywords: CDC percentiles • modified-scaled percentiles • estimated-adult *BMI* • specific *BMI* • parabola fitting • circle fitting • Growth-and-Obesity Vector-Roadmap 2.6

Abbreviations: ***BMI*****:** **B**ody-**M**ass **I**ndex • **CDC:** **C**enters for **D**isease **C**ontrol and Prevention • **ICP:** **I**nfancy-**C**hildhood-**P**uberty • **NCHS:** **N**ational **C**enter for **H**ealth **S**tatistics • **NGDS:** **N**ational **G**rowth and **D**evelopmental **S**tandards for the **P**akistani **C**hildren • $^{\mathbf{P}}$**:** **p**ercentile • **SGPP:** **S**ibling **G**rowth **P**ilot **P**roject • **WHO:** **W**orld **H**ealth **O**rganization

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

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INTRODUCTION

Gymnastics are understood to be *exercises developing the muscles*. These are, essentially, grammar or anatomy of locomotion — joint mobility and muscle tone, which need power, physical strength, grace, flexibility, coördination, balance as well as agility, requiring concentration and devotion. Competitive gymnastic events are governed by Fédération Internationale de Gymnastique (FIG). It, also, has the responsibility to affiliate national governing bodies. 'Gymnastics' is taken from adjective in Greek *γυμνός* (*gymnos*), which bears the meaning 'naked'. The verb related to this adjective *γυμνάζω* (*gymnazo*) implies 'to train naked'. Gymnastics is derived from Latin *gymnasticus* as well as Greek *gymnastikos* (skilled in/liking bodily exercise) and *gymnazein* (to train/to exercise). This sport became common in 1570s. In ancient times, gymnasts exercised sans clothing.

This paper deals with the problem of assignment of build as gymnastic teams and coaching sessions are formed according to build. The attire of preteen gymnasts is, also, based on their age and build. Hence, it becomes very important to assign build in a correct manner. Since build is determined by a sum of height and mass percentiles, there is a need to scale percentiles, based on tools of mathematics and statistics, till the availability of charts and tables, which are constructed based on data collected indigenously through reliable and reproducible techniques. Heights and masses of 1666 children, belonging to all regions of Pakistan, were measured during 1998-2016. Modified-scaled percentiles are generated by fitting parabolic curves for height data and circles for mass data. The method presented in this paper is not limited to Pakistan and could be applied to data collected for residents of other countries, like, Turkey.

THE GAME OF GYMNASTICS

Gymnastics is associated with physiological functioning of the body, for overall development of the human skeleton and bones (Joseph, 1949). Its coaching involves different components**:** aesthetic, cognitive, creative, physical, and psychological as well as skills, with or without apparatus (Caroll, Manners, 2003). Hayman, Polman, Wharton, Borkoles (2020) discussed applicability of role strain theory in understanding developmental experiences of international junior acrobatic gymnasts. Judd, Barnett, Farrow, Berry, Borkoles, Polman (2017*a*, *b*) evaluated effectiveness of 16 weeks gymnastics curriculum and studied the impact of gymnastics on children's physical self-concept and movement skill development in primary schools. Kaldas, Bission, Hogue, Apinis, Berbiche, Gaureault (2017) constructed validity and inter-rater reliability of the Gymnastic Functional Measurement Tool in the classification of female competitive gymnasts in Canada. Petković and co-workers studied strength, speed, flexibility and motor skills of Serbian gymnasts (Petković, 2017; Petković, Lilic, Kinov, *et al.* 2016; Petković, Tankusheva, Stanković, Nimčević, 2016; Petković, Nimčević, Stanković, Piršl, 2017). Potop, Urichianu (2017) deliberated in the use of technologies for achievement of the learning units of aerobatic gymnastics in the primary school.

PSYCHOLOGICAL AND PHYSICAL EXAMS AS WELL AS FITNESS TESTING

The importance of pre-participation (safety considerations) and end-of-the-term (performance considerations) psychological and physical examinations as well as fitness testing cannot be over-emphasized (Kamal, Azeemi, Khan, 2017). The former plays the role in detecting conditions, which affect the general health of players as well as their teammates, coaches (including researchers involved in improving safety and enhancing performance), health team (physiotherapists, doctors, *etc.*) and administrative staff — the most significant under the current circumstances is testing for viral and bacterial diseases, in particular, COVID-19. The later has the basic purpose of documenting changes in health and fitness statuses because of sport participation (Kamal, Khan, 2014). Both health-related as well as skill-related fitness need to be assessed (Kamal, Khan, 2013). Physical examination of the

Table 1. Maturity levels of gymnasts related to ages

Maturity Levels[ξ]	*Related to*[ϖ]
Physical	Chronological, phenotypic and skeletal ages
Mental	Developmental age
Social	Developmental age
Spiritual	Developmental age

[ξ] Maturity levels taken from Andrews, Smith, Squance, Russell (1963); these 4 interrelated levels have been discussed in detail in Kamal, Jamil (2012)

[ϖ] Adapted from Kamal, Ansari, M.J., Ansari, S. A., Naz (2020)

disrobed gymnast should include thorough examination of the spinal column to look for presence of scoliosis (Kamal, Raza, Sarwar, 2016; 2020) as well as gait analysis (Kamal, Rajput, Ansari, 2016).

Maturity Level

As part of the psychological examination, maturity level of the gymnasts should be evaluated (Table 1) based on categories of age (Table 2).

Classification of Puberty

The study of morphological characteristics and biological maturation of gymnasts is of utmost interest to researchers (Batista. Garganta, Ávila-Carvalho, 2019). A brief overview of classification of puberty is presented here. Those gymnasts, who are showing no signs of attaining puberty, are classified as 'prepubertal gymnasts'. Gymnasts, who are about to enter puberty, are termed as 'peripubertal gymnasts'. Their height function levels off, which means the height velocity vanishes, according to ICP model of Karlberg (1987). Those gymnasts, who have started to enter puberty, are classified as 'pubertal gymnasts'. 'Adolescents' are gymnasts, who have, already, attained puberty. 'Adults' are those gymnasts, who have completed the process of gaining puberty and show the trend of attaining their maximum height (height velocity approaches close to zero). This occurs around the age

Table 2. Different categories of age important for a gymnast's performance[Θ]

Chronological	Determined by taking difference of date of age computation and date of birth [τ]
Developmental	Age at which the gymnast's brain functions
Phenotypic	Age at which the gymnast's body functions — also called 'Biological Age'
Skeletal	Age at which gymnast's skeleton is formed — also termed as 'Osseous Age'[κ]

[Θ] Adapted from Kamal, Ansari, M. J., Ansari, S. A., Naz (2020)

[τ] Kamal, Jamil, Khan. (2011) provides a method to compute this age in *decimal years*

[κ] Determined by studying X rays of bones

of 20 *years*. Table 3 gives the approximate Tanner classification linked to stages of puberty, proposed earlier (Kamal, Azeemi, Khan, 2017). The mathematical equations cum inequalities describing 'normal puberty', 'early puberty', 'excessively-early puberty', 'delayed puberty', 'excessively-delayed puberty' and 'precarious puberty', with the definitions of excessively early puberty and precarious puberty,

Table 3. Tanner scoring and stages of puberty

Tanner Score[θ]	*Stage of Puberty*
1	Prepubertal
2	Peripubertal
3	Pubertal
4	Adolescent
5	Adult

[θ]Tanner (1962)

Normal Puberty

$$\mu_{\text{Onset–Puberty}} - \sigma_{\text{Onset–Puberty}} \leq A_{\text{Onset–Puberty}} \leq \mu_{\text{Onset–Puberty}} + \sigma_{\text{Onset–Puberty}}$$

where $A_{\text{Onset–Puberty}}$ represents age of onset of puberty for a gymnast, $\mu_{\text{Onset–Puberty}}$ gender-specific mean age of onset of puberty for a certain country and $\sigma_{\text{Onset–Puberty}}$ gender-specific standard deviation for age of onset of puberty for that country

Delayed Puberty (Late Bloomer)

$$\mu_{\text{Onset–Puberty}} + \sigma_{\text{Onset–Puberty}} < A_{\text{Onset–Puberty}} \leq \mu_{\text{Onset–Puberty}} + 2\sigma_{\text{Onset–Puberty}}$$

Excessively Delayed Puberty (Very-Late Bloomer)

$$A_{\text{Onset–Puberty}} > \mu_{\text{Onset–Puberty}} + 2\sigma_{\text{Onset–Puberty}}$$

Early Puberty (Early Bloomer)

$$\mu_{\text{Onset–Puberty}} - 2\sigma_{\text{Onset–Puberty}} \leq A_{\text{Onset–Puberty}} < \mu_{\text{Onset–Puberty}} - \sigma_{\text{Onset–Puberty}}$$

Excessively Early Puberty (Very-Early Bloomer)

$$A_{\text{Onset–Puberty}} < \mu_{\text{Onset–Puberty}} - 2\sigma_{\text{Onset–Puberty}}, \; P_{\text{Scaled}}^{\text{MOD}}(h) + P_{\text{Scaled}}^{\text{MOD}}(\mu) \geq 100$$

Precarious Puberty

$$A_{\text{Onset–Puberty}} < \mu_{\text{Onset–Puberty}} - 2\sigma_{\text{Onset–Puberty}}, \; P_{\text{Scaled}}^{\text{MOD}}(h) + P_{\text{Scaled}}^{\text{MOD}}(\mu) < 100$$

Figure 1. Classification of puberty based on age of onset of puberty

proposed earlier (Kamal, Azeemi, Khan, 2017), altered based on modified-scaled percentiles of height, $P_{\text{Scaled}}^{\text{MOD}}(h)$, and mass, $P_{\text{Scaled}}^{\text{MOD}}(\mu)$, are given in Figure 1.

For peripubertal gymnasts, it is important to perform puberty rating at every physical examination and Tanner score assigned. The significance of this exercise is evident from work of Albertsson-Wikland, Niklasson, Holmgren, Gelander, Nierop (2020), who are in the process of developing a new type of pubertal height reference for improved growth evaluation during puberty, considering individual variation in pubertal timing.

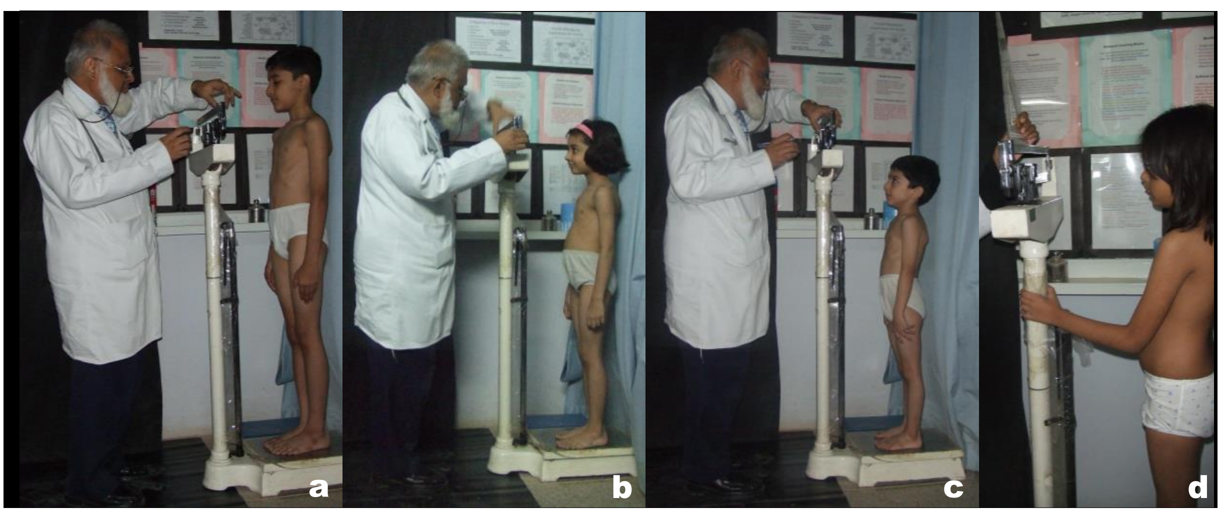
Figures 2*a-d*. Feet (*a*) and head (*b*) positioning for stature determination (set-square placement); (*c*, *d*) heights of children measured in Growth-and-Imaging Laboratory — (*c*) first appeared in Kamal, Ansari, Jamil (2015) and (*d*) in Kamal, Jamil (2014)

ANTHROPOMETRY OF GYMNASTS

Anathropometry of gymnasts participating in various tournaments is a routine practice (Silva, M. –R. G., Silva, H. –H., Luemba, 2020). The most important anthropometric measures, employed in determining Growth-and-Obesity Vector-Roadmaps (Kamal, M. J. Ansari, S. A. Ansari, Naz, 2020) are measurements of heights and masses according to agreed-upon standards. Height and weight monitoring of gymnasts at regular intervals is mandatory for an effective training program (Kamal, 2008). For measuring of height (stature), the stripped student gymnast is instructed to stand touching the mounted engineering tape (vertical alignment checked through plumb line) and asked to align hands with body, palms touching thighs and heels together. Height was obtained with the gymnast in attention position (full inhaling to get maximum expansion of chest and tummy in). A pencil is held at eye level to make sure that chin of the gymnast is parallel to floor (Figures 2*a*-*d*). For recording of mass (weight), the undressed student gymnast is asked to step on the beam scale (central position) in stand-at-ease position, palms on thighs and feet separated, looking straight and breathe in to trap maximum air (Figures 3*a*-*d*). A standard 100-*cm* ruler and a standard 2-*kg* mass were employed to calibrate height- and mass-measurement instruments at the start of each daily session along with recording of zero errors. Removal of all clothes except short underpants ensures proper posture, non-flexing of elbows and knees as well as complete inhaling. Detailed manual for obtaining these measurements has been prepared by the first author (Kamal, 2016*a*). Step-by-step procedures illustrated with labeled photographs are given in **Additional File 1**. Measurements were obtained by anthropometrists with documented accuracy and precision (Kamal, Razzaq, Jamil, 2013) — definitions of accuracy and precision available in Kamal (2009). The demographic and the clinical data were recorded in a structured form. Date of birth, gender, parents' education and occupation as well as details of siblings were included in the demographic data. A software developed indigenously, SOFTGROWTH, was used to generate Growth-and-Obesity Vector-Roadmap of gymnasts.

GROWTH CHARTS AND TABLES

Growth charts are graphs, which display height or mass gain during a time span. These charts represent a time series. Growth tables are matrices, with rows showing height or mass values for a certain age over percentile range 3^P-97^P (for CDC); columns representing values of height and mass for a certain percentile over age range 2-20 *years*. Growth charts and tables are constructed by collecting heights



Figures 3*a*-*d*. (*a*) Mass of a boy measured and (*b*-*d*) common errors in mass-measurement protocols**:** (*b, c*) toes not in the same line, (*b*) child wearing hair band, (*c*) child looking up, palm not positioned on thigh, (*d*) child holding on to beam scale — (*a*) first appeared in Kamal, Jamil (2012) and (*c*) in Kamal, Ansari, Jamil (2015)

and masses of many youngsters, both boys and girls, over the entire growth period. Using these charts and tables, the measured anthropometric variables of child gymnasts, may be compared by matching gender and age to figure out whether growth of that particular gymnast falls within normal limits.

There is a need to develop local growth charts and tables for each country with regular updating. Throughout the developed world, this practice is standard, *e. g.*, Japan (Isojima, Kato, Ito, Kanzaki, Murata, 2016), Poland (Kulaga, Litwin, Tkaczyk, *et al.*, 2011), Romania (Pascanu, Pop, Barbu, *et al.*, 2016), Korea (Kim, Yun, Hwang, *et al.*, 2018). CDC Growth Charts and Tables are revised version of growth charts developed by NCHS, which is a part of CDC. These charts have well shaped percentile curves for boys and girls displaying variation of percentiles of height and mass with ages. For developing these growth standards, 5 national health surveys were conducted in the United States. These charts were inadequate to deal with many extreme cases found in the Pakistani children during 1998-2013. Hence, these charts and tables were extended to include percentile range 0.01^{P}-99.99^{P} and were termed as Extended Growth Charts and Tables (Kamal, Jamil, 2014).

In the absence of customized growth charts and tables for many developing countries, statistical methods have been employed to adjust international growth curves for local use (Abolfotouh, Abu-Zeid, Badawi, Mahfouz, 1993). Some preliminary attempts have been made to generate the Pakistani Growth Charts (Aziz, Noor-ul-Ain, Majeed, *et al.*, 2012; Mushtaq, M. U., Gull, Musahtaq, K. *et al.*, 2012; Iftikhar, Khan, Siddiqui, Baig-Ansari, 2018).

WHO initiated a process to recognize available sets of measures of anthropometric variables obtained in various countries, selecting 115 candidate-sets from 45 countries, later on reduced to 34 sets, which came from 22 countries satisfying criteria for inclusion. These were used to reconstruct the 1977 NCHS/WHO growth reference for 5-19-*year*-old boys and girls.

ASSIGNMENT OF BUILD

Kamal, Khan (2015) proposed mathematical criteria to assign build of gymnast by looking at the sum of percentiles of height and mass of the player. If the sum is less than 50, the gymnast has ‘small’ build. Else if, equal to or more than 50 but less than 150, the gymnast has ‘medium’ build. Else, the gymnast has ‘big’ build. The main purpose of determining this paramter is to form sport teams according to build. However, the first author suggested dividing students classroom sections, also, according to build, so that taller students are not forced to sit in the back of class and the students could be required to reshuffle seats halfway through a session in order to increase concentration, make new friends and break-up mischief groups (Kamal, 2015*c*; Kamal, Khan, 2018).

SCALING OF PERCENTILES

Kamal, Azeemi, Khan (2017) scaled Extended Growth Charts and Tables (generated from CDC Growth Charts and Tables), so that they fit better to the growth profile of the Pakistani children, by mapping 40^{P} (CDC) to 50^{P} (scaled), 0 to 0 and 100^{P} to 100^{P}. Equations (1*a*, *b*) were obtained by fitting parabolic curves. It could be easily verified that scaled percentiles were less than 100^{P} for all CDC percentiles less than 100^{P}.

(1*a*, *b*) $$P_{\text{Scaled}}(h) = \frac{17 P_{\text{CDC}}(h)}{12} - \frac{P^2_{\text{CDC}}(h)}{240}, \; P_{\text{Scaled}}(\mu) = \frac{17 P_{\text{CDC}}(\mu)}{12} - \frac{P^2_{\text{CDC}}(\mu)}{240}$$

For assignment of build CDC percentiles of height, $P_{\text{CDC}}(h)$, and mass, $P_{\text{CDC}}(\mu)$, in the formulae for build were replaced by scaled percentiles, $P_{\text{Scaled}}(h)$ and $P_{\text{Scaled}}(\mu)$, respectively, *i. .e.*, a gymnast with small build had sum of scaled percentiles less than 50, and so on.

Table 4. Scaling of percentiles to be used for the Pakistani gymnasts**:** general case illustrating mapping of median of the processed data, p^P (CDC percentile) to 50^P (percentile of the Pakistani population)

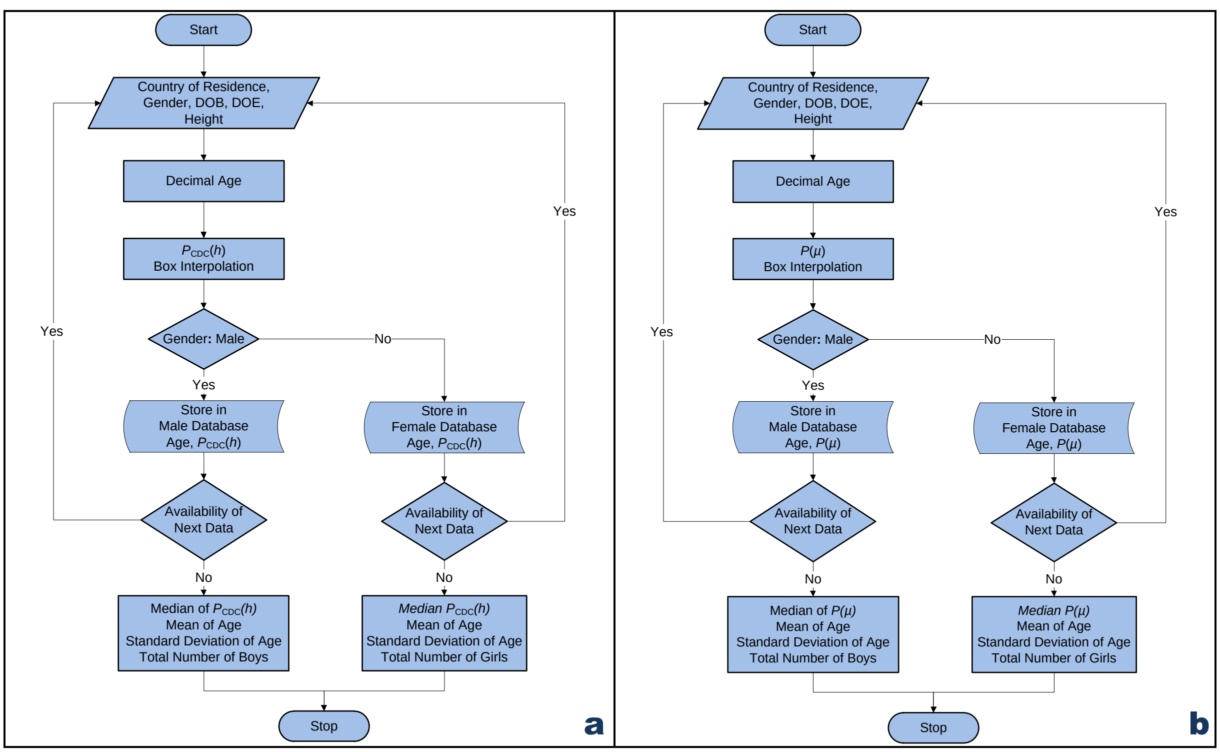
CDC Percentile	→	*Modified-Scaled Percentile*
0	→	0
p^P	→	50^P
100^P	→	100^P

MODIFIED-SCALED PERCENTILES

Scaling of percentiles given by Equations (1*a*, *b*) was accomplished through mapping 40^P (CDC) to 50^P (scaled), based on suggestion given in Kamal, Ansari, Jamil (2015). Therefore, it was decided to map median of CDC percentiles of collected data, say p^P to 50^P of the Pakistani population to generate 4 equations, one each for transforming height percentiles for boys, height percentiles for girls, mass percentiles for boys and mass percentiles for girls (Table 4). Figures 4*a*, *b* give steps for computation of median of CDC percentiles of height and mass based on indigenous data of 1666 children collected during 1998-2016 as part of the NGDS Pilot Project. Different programs for processing were written in order to allow data of children to be processed, whose one of the anthropometric measures (height or mass) is not recorded.

Since 3 values of CDC percentile, P_{CDC}, are mapped to 3 values of modified-scaled percentile, $P_{\text{Scaled}}^{\text{MOD}}$, suitable to be used for the data collected from the Pakistani population (Table 4), a parabolic curve should be fitted — Equation (A-1) in Appendix A

(2) $$P_{\text{Scaled}}^{\text{MOD}} = aP_{\text{CDC}}^2 + bP_{\text{CDC}} + c$$



Figures 4*a*, *b*. Flow charts showing steps for computation of median of boys' and girls' CDC percentiles of (*a*) height and (*b*) mass based on indigenous data collected during 1998-2016

The adjective 'modified-scaled' is used to differentiate these percentiles from the ones introduced earlier (Kamal, Azeemi, Khan, 2017). Substituting the values from Table 4 in Equation (2) and solving the system of equations

(3*a*) $$P_{\text{Scaled}}^{\text{MOD}} = 0,\ P_{\text{CDC}} = 0 \Rightarrow 0 = 0 + 0 + c \Rightarrow c = 0$$

(3*b*) $$P_{\text{Scaled}}^{\text{MOD}} = 100,\ P_{\text{CDC}} = 100 \Rightarrow 100 = (100)^2 a + 100b \Rightarrow 1 = 100a + b \Rightarrow b = 1 - 100a$$

(3*c*) $$P_{\text{Scaled}}^{\text{MOD}} = 50,\ P_{\text{CDC}} = p \Rightarrow 50 = p^2 a + pb = 0 \Rightarrow 50 = p^2 a + p(1 - 100a) \Rightarrow a = -\frac{50 - p}{p(100 - p)}$$

one obtains

(4*a*-*c*) $$a = -\frac{50 - p}{p(100 - p)},\ b = 1 - 100a = \frac{5000 - p^2}{p(100 - p)},\ c = 0$$

Equation (2), therefore, may be written as

(5) $$P_{\text{Scaled}}^{\text{MOD}} = \frac{5000 - p^2}{p(100 - p)} P_{\text{CDC}} - \frac{50 - p}{p(100 - p)} P_{\text{CDC}}^2$$

It can be, easily, verified that Equation (5) satisfies the conditions set forth in Table 4**:**

a) If $P_{\text{CDC}} = 0$, it is, immediately, seen that $P_{\text{Scaled}}^{\text{MOD}} = 0$, *i. e.*, $0 \rightarrow 0$

b) Putting $P_{\text{CDC}} = p$, Equation (3) takes the form

$$P_{\text{Scaled}}^{\text{MOD}} = \frac{(5000 - p^2)p}{p(100 - p)} - \frac{(50 - p)p^2}{p(100 - p)} = \frac{5000p - p^3 - 50p^2 + p^3}{p(100 - p)} = \frac{50p(100 - p)}{p(100 - p)} = 50$$

i. e., $p^{\text{P}} \rightarrow 50^{\text{P}}$

c) Substituting $P_{\text{CDC}} = 100$, one obtains

$$P_{\text{Scaled}}^{\text{MOD}} = \frac{(5000 - p^2)}{p(100 - p)}(100) - \frac{(50 - p)}{p(100 - p)}(100)^2 = \frac{500000 - 100p^2 - 500000 + 10000p}{p(100 - p)} = \frac{100p(100 - p)}{p(100 - p)}$$

which reduces to $P_{\text{Scaled}}^{\text{MOD}} = 100$, *i. e.*, $100^{\text{P}} \rightarrow 100^{\text{P}}$

The method is general and could be applied to population of any country by fitting indigenously collected data to Equation (5). Tables 5*a*, *b* give median of percentile for a representative sample of the Pakistani population. Table 4 is now transformed into Table 6, when median values of CDC percentile of height from Table 5*a* and median values of CDC percentile of mass from Table 5*b* are substituted in place of '*p*'. Equations (6*a*-*d*) are generated from Equation (5) by substituting these values of '*p*'.

Table 5*a*. Median CDC percentile of height determined to compute modified-scaled percentiles

Data Collected during 1998-2016	*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}

Table 5*b*. Median CDC percentile of mass determined to compute modified-scaled percentiles

Data Collected during 1998-2016	*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 Mass		
Median	22.99109832^{P}	19.92558247^{P}

(6*a*) $$P_{\text{B-Scaled}}^{\text{MOD}}(h) = 1.27658744395554\, P_{\text{B-CDC}}(h) - 0.00276587443955 54\, P_{\text{B-CDC}}^{2}(h)$$

(6*b*) $$P_{\text{G-Scaled}}^{\text{MOD}}(h) = 1.66712927583779 9\, P_{\text{G-CDC}}(h) - 0.00667129275837 8\, P_{\text{G-CDC}}^{2}(h)$$

(6*c*) $$P_{\text{B-Scaled}}^{\text{MOD}}(\mu) = 2.52547914881378 5\, P_{\text{B-CDC}}(\mu) - 0.01525479148813 79\, P_{\text{B-CDC}}^{2}(\mu)$$

(6*d*) $$P_{\text{G-Scaled}}^{\text{MOD}}(\mu) = 2.88491777946 24\, P_{\text{G-CDC}}(\mu) - 0.01884917779462 4\, P_{\text{G-CDC}}^{2}(\mu)$$

where $P_{\text{B-Scaled}}^{\text{MOD}}(h)$ and $P_{\text{B-CDC}}(h)$ represent modified-scaled and CDC percentiles of height for boys; $P_{\text{G-Scaled}}^{\text{MOD}}(h)$ and $P_{\text{G-CDC}}(h)$ modified-scaled and CDC percentiles of height for girls; $P_{\text{B-Scaled}}^{\text{MOD}}(\mu)$ and $P_{\text{B-CDC}}(\mu)$ represent modified-scaled and CDC percentiles of mass for boys and $P_{\text{G-Scaled}}^{\text{MOD}}(\mu)$ and $P_{\text{G-CDC}}(\mu)$ modified-scaled and CDC percentiles of mass for girls. In order to make sure that all values of modified-scaled percentiles lie in the range $0 \le P_{\text{Scaled}} < 100$ (domain being $0 \le P_{\text{CDC}} < 100$), the parabolic curve must not have an extremum (maximum or minimum value) inside this range. Differentiating Equation (5), equating the derivative to zero and solving for P_{CDC}, one gets

Table 6. Scaling of percentiles to be used for the Pakistani gymnasts**:** specific values obtained by processing indigenous data[ø]

CDC Percentile	→	*Modified-Scaled Percentile*
***a*. Scaling of Height Percentiles for Boys** 🚹		
0	→	0
43.21272955^{P}	→	50^{P}
100^{P}	→	100^{P}
***b*. Scaling of Height Percentiles for Girls** 🚺		
0	→	0
34.85247886^{P}	→	50^{P}
100^{P}	→	100^{P}
***c*. Scaling of Mass Percentiles for Boys** 🚹		
0	→	0
22.99109832^{P}	→	150^{P}
100^{P}	→	100^{P}
***d*. Scaling of Mass Percentiles for Girls** 🚺		
0	→	0
19.92558247^{P}	→	150^{P}
100^{P}	→	00^{P}

ø Compare with Table 7 of Kamal, Azeemi, Khan. (2017), in which 40^{P} CDC (height, mass) percentile is mapped to 50^{P} scaled (height, mass) percentile

(7) $$0=\frac{dP^{\text{MOD}}_{\text{Scaled}}}{dP_{\text{CDC}}}=\frac{5000-p^2}{p(100-p)}-\frac{2(50-p)}{p(100-p)}P_{\text{CDC}}\Rightarrow P_{\text{CDC}}\big|_{P_{\text{CDC}}=P_0}=\frac{5000-p^2}{100-2p}$$

P_0 is the point where extremum occurs. This extremum is a maximum (the parabola goes down from this point) in all our cases. This can be checked by looking at the second derivative

(8) $$\left.\frac{d^2P^{\text{MOD}}_{\text{Scaled}}}{dP^2_{\text{CDC}}}\right|_{P_{\text{CDC}}=P_0}=-\frac{2(50-p)}{p(100-p)}=\frac{2p-100}{p(100-p)}<0 \text{ (condition for maximum of curve)}$$

as $p<50$ in all the cases as shown in Table 6. Substituting the values of p from Table 6 in Equation (7), this maximum occurs at**:**

a) $P_0=230.774655\,8735225$ $(p=43.21272955)$, for the curve produced by Equation (6*a*). CDC percentiles are transformed in a proper fashion keeping the modified-scaled percentiles in the permitted range $(0\le P^{\text{MOD}}_{\text{B-Scaled}}<100)$. To prove the above statement, Equation (6*a*) is differentiated

$$\frac{dP^{\text{MOD}}_{\text{B-Scaled}}(h)}{dP_{\text{B-CDC}}(h)}=1.2765874439\,5554-0.0055317488\,791108\,P_{\text{B-CDC}}(h)>0.72341255\,604446$$

when $P_{\text{B-CDC}}(h)<100$, indicating that modified-scaled percentiles of height for boys are monotonically increasing with the CDC percentiles of height for boys. In other words,

$$P_{\text{B-CDC2}}(h)>_{\text{B-CDC1}}(h)\Rightarrow P^{\text{MOD}}_{\text{B-Scaled2}}(h)>P^{\text{MOD}}_{\text{B-Scaled1}}(h)$$

This completes the proof.

b) $P_0=124.947992\,5569278$ $(p=34.8547886)$, for the curve produced by Equation (6*b*). CDC percentiles are transformed in a proper fashion keeping the modified-scaled percentiles in the permitted range $(0\le P^{\text{MOD}}_{\text{G-Scaled}}<100)$. To prove the above statement, Equation (6*b*) is differentiated

$$\frac{dP^{\text{MOD}}_{\text{G-Scaled}}(h)}{dP_{\text{G-CDC}}(h)}=1.66712927\,5837799-0.01334258\,5516756\,P_{\text{G-CDC}}(h)>0.33287072\,4162199$$

when $P_{\text{G-CDC}}(h)<100$, indicating that modified-scaled percentiles of height for girls are monotonically increasing with the CDC percentiles of height for girls. In other words,

$$P_{\text{G-CDC2}}(h)>P_{\text{G-CDC1}}(h)\Rightarrow P^{\text{MOD}}_{\text{G-Scaled2}}(h)>P^{\text{MOD}}_{\text{G-Scaled1}}(h)$$

This completes the proof.

c) $P_0=82.7765869\,7523337$ $(p=22.99109832)$, for the curve produced by Equation (6*c*), which generates values of modified-scaled percentiles exceeding 100 for CDC percentiles in the permitted range $(0\le P_{\text{Scaled}}<100)$. Counter example is given below**:**

$$P_{\text{CDC}}=82.7765869\,7523337\Rightarrow P^{\text{MOD}}_{\text{Scaled}}=104.525269\,7450295$$

d) $P_0=76.5263559\,7413728$ $(p=19.92558247)$, for the curve produced by Equation (6*d*), which generates values of modified-scaled percentiles exceeding 100 for CDC percentiles in the permitted range $(0\le P_{\text{Scaled}}<100)$. Counter example is given below**:**

$$P_{\text{CDC}}=76.5263559\,7413728\Rightarrow P^{\text{MOD}}_{\text{Scaled}}=110.386122\,4736286$$

It should be noted that both equations of parabola for scaled percentiles of height and mass fitted nicely in the previous model (Kamal, Azeemi, Khan, 2017). In that model, maximum of parabola occurred at $P_0=170$ $(p=40)$. It could be easily proved that the CDC percentiles transformed in a proper fashion keeping the scaled percentiles in the permitted range $(0\le P_{\text{Scaled}}<100)$.

In order to alleviate the above problem for equations of mass-percentile, Equations (6*c*, *d*), circles are fitted to 3 points mentioned in Table 6 (sections *c*, *d*). Substituting $P_{\text{CDC}} = 0$ and $P_{\text{Scaled}}^{\text{MOD}} = 0$ in the general equation of circle — Equation (B-2) in Appendix B

(9*a*) $$P_{\text{CDC}}^{2}(\mu) + P_{\text{Scaled}}^{\text{MOD}\,2}(\mu) + 2fP_{\text{CDC}}(\mu) + 2gP_{\text{Scaled}}^{\text{MOD}}(\mu) + c = 0$$

one gets $c = 0$. Next, substituting $P_{\text{CDC}} = 100$ and $P_{\text{Scaled}}^{\text{MOD}} = 100$, one obtains

$$f + g = -100 \Rightarrow g = -(f + 100)$$

Now $P_{\text{CDC}} = p$ and $P_{\text{Scaled}}^{\text{MOD}} = 50$, gives

$$f = \frac{7500 - p^2}{2(p-50)} \Rightarrow g = -(f + 100) = \frac{p^2 - 200p + 2500}{2(p-50)}$$

Putting these values in (9*a*), one obtains

(9*b*) $$(p-50)\left(P_{\text{CDC}}^{2}(\mu) + P_{\text{Scaled}}^{\text{MOD}\,2}(\mu)\right) + (7500 - p^2)P_{\text{CDC}}(\mu) + (p^2 - 200p + 2500)P_{\text{Scaled}}^{\text{MOD}}(\mu) = 0$$

Substituting the values of *p* from Table 6 (sections *c*, *d*) and solving for scaled percentiles in terms of CDC percentiles, equations for conversion of CDC mass percentiles to scaled mass percentiles are obtained as

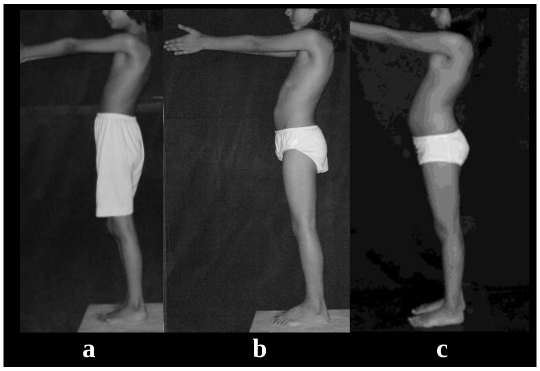
(10*a*) $$P_{\text{B-Scaled}}^{\text{MOD}}(\mu) = -29.0576242 + \sqrt{844.3455241 + 258.1152484\,P_{\text{B-CDC}}(\mu) - P_{\text{B-CDC}}^{2}(\mu)}$$

(10*b*) $$P_{\text{G-Scaled}}^{\text{MOD}}(\mu) = -18.00899207 + \sqrt{327.1031092 + 236.1798414\,P_{\text{G-CDC}}(\mu) - P_{\text{G-CDC}}^{2}(\mu)}$$

Modified-scaled mass percentiles now do not exceed 100, when CDC mass percentiles are below 100 for both genders. Figures 5*a*-*c* give posture photographs of children (eyes cropped to protect privacy), whose build was computed using modified-scaled percentiles.

Realizing that small build indicates dominance of brain function over body function, whereas big build indicates dominance of body function over brain function (Figure 6), same curriculum could be taught to all sections, with more creative-thinking and critical-analysis questions added for students of small-build section (Kamal, Siddiqui, 1986), whereas more hands-on-experimental activities should be included for students of big-build section (Kamal, 2009), once the classrooms sections are formed according to build (Kamal, 2015*c*).

The above computations of scaling by fitting parabolas (for height percentiles) and circles (for mass



Figures 5*a*-*c*. Posture photographs of children exhibiting (***a***) small build — GR**:** SGPP -KHI-20110412-02/02; age 7 *years* 6 *months* 11 *days* on May 13, 2012; sum of modified-scaled percentiles 6.26; (***b***) medium build — ZHZ**:** SGPP-KHI-20110412-01/01; age 6 *years* 10 *months* 27 *days* on May 13, 2012; sum of modified -scaled percentiles 110.62 and (***c***) big build — LG**:** SGPP-KHI-20131021-02/01; age 8 *years* 7 *months* 11 *days* on March 26, 2016; sum of modified-scaled percentiles 190.51 — Figures *a*, *b* first appeared in Kamal (2015*a*, *b*), respectively; same build computed using scaled percentiles (Figures 5*a*-*f* in Kamal, Azeemi, Khan, 2017)

Classification	*Modified-Scaled-Percentile Range*	*Dominating Function*	*Suitable for*
Small	$P^{\text{MOD}}_{\text{Scaled}}(h) + P^{\text{MOD}}_{\text{Scaled}}(\mu) < 50$	**Brain**	**Intellectual work, planning and development**
Medium	$50 \leq P^{\text{MOD}}_{\text{Scaled}}(h) + P^{\text{MOD}}_{\text{Scaled}}(\mu) < 150$	**Brain and body equally contributing**	**May adapt to body- or brain-dominating tasks**
Big	$150 \leq P^{\text{MOD}}_{\text{Scaled}}(h) + P^{\text{MOD}}_{\text{Scaled}}(\mu)$	**Body**	**Tasks involving strength and speed**

Figure 6. Classification of build of a child gymnast on the basis of modified-scaled percentiles

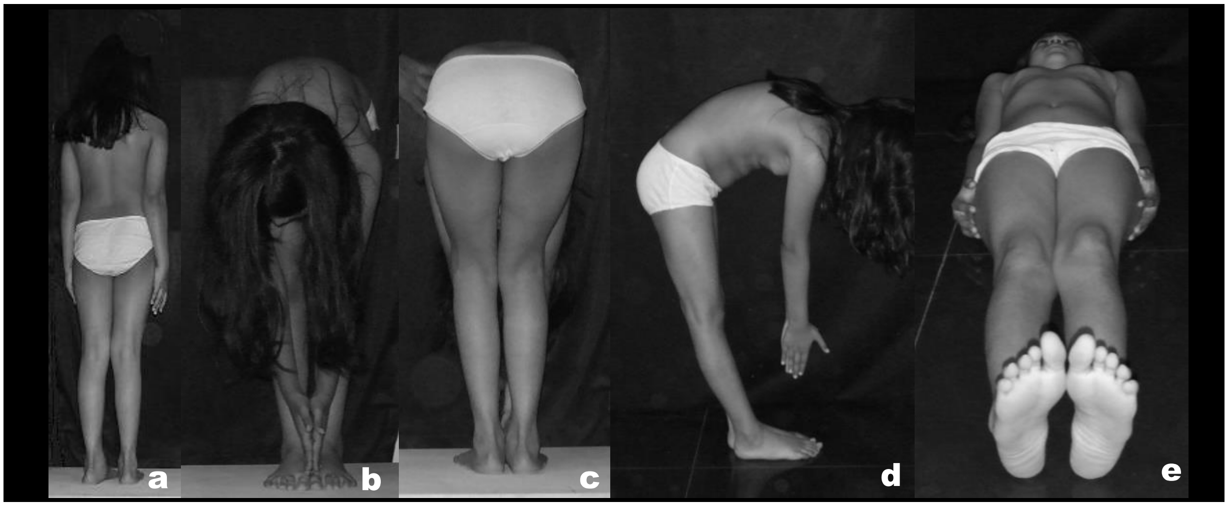
percentiles) should be an essential part of course work of sports and anthromathematics (Kamal, 2014; 2016*b*).

GROWTH-AND-OBESITY VECTOR-ROADMAP 2.6 OF A GYMNAST

In this section, the authors give Growth-and-Obesity Vector-Roadmap 2.6 of a gymnast LG for her 4 checkups. Figure 7 gives highlights of history and physical examinations of LG, Figures 8*a*-*k* show posture as well as forward bending and mild stretching photographs of LG. Growth-and-Obesity Vector-Roadmap 2.6 is an enhancement of Growth-and-Obesity Vector-Roadmap 2.5 (Kamal, M. J. Ansari, S. A. Ansari, Naz, 2020), in the sense that modified-scaled percentiles are used in place of scaled percentiles for assignment of build. Color coding used in Growth-and-Obesity Vector-Roadmap 2.6 is explained in **Additional File 2** and detailed procedure to construct Growth-and-Obesity Vector-Roadmap 2.6 is given in **Additional File 3**. Growth-and-Obesity Vector-Roadmap 2.6 of LG has 2 major portions, viz. mathematical analysis of checkups conducted (Tables 7*a*-*c*) and recommendations for actions to be performed during the next 6 *months* regarding height and mass management as well as safe sun exposure time periods for acquiring recommended dose of vitamin D (Tables 7*d*, *e*). Tables 7*a*, *b* have been divided into 4 portions — vital statistics (yellow portion), height data (blue portion), mass data (pink portion) as well as height and mass data combined (green portion). Table 7*b* exhibits **pseudo-gain of mass** between 3rd and 4th checkups (mass gain accompanied by drop in CDC percentile-of-mass for 2 consecutive checkups) — mass put-on from **28.21 *kg*** to **29.975 *kg***, CDC percentile-of-mass dropping from **68.54^{P}** to **65.29^{P}** (Kamal, Jamil, Razzaq, 2014). Extended Growth

LG: Female, 7+ at the first checkup, biological child
Family History: Non-cousin marriage, blood group B+ of father and mother, both parents working, graduates in medical science, father has cardiac problems, mother diabetic and has congenital optic nerve weakness
Pregnancy, Delivery and Neonatal: Pregnancy normal, cesarean delivery after 36 weeks of pregnancy, birth length 41.65 *cm*, birth mass 3.5 *kg*, blood group B+, jaundice at birth, weaning mode — bottle
Sleep Pattern and Diet Habits: 9-10 hour sleep, 3 balanced meals, 2 balanced snacks (both parents studied nutrition in undergraduate work)
Academics and Social Interaction: Reserved, independent, bold, academically doing well, behavior in lab good, quiet, coöperative, tried to replicate anthropometric techniques on father
Sports and Co-Curricular Activities: Racing, gymnastics, dancing and music
Physical Examination: LG 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). Visual, forward bending and moiré examinations of the spinal column were performed, lips bluish, teeth rough on edges, nails whitish with white spots, toes converging observed in gait away and towards, midline of back S shaped, shoulders, scapulae and spinal dimples uneven, body triangles not equal and plumb-line not aligned, front and back, not able to touch toes

Figure 7. History and physical examination of LG, a girl participating in gymnastics



Figures 8*a-e*. Posture and forward bending photographs of LG**:** (*a*) posture of back; (*b*)-(*d*) forward-bending tests; (*e*) posture with the child supine — (*a*)-(*c*) taken on November 22, 2014; (*d*), (*e*) on March 26, 2016

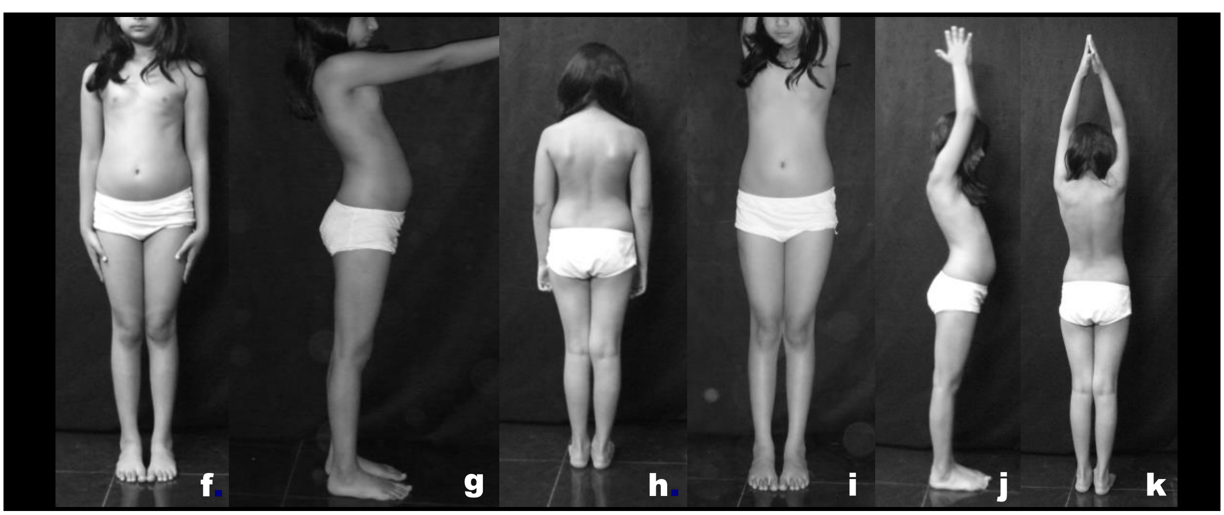
Tables have been used to construct Roadmap 2.6 — Additional File 3 of Kamal, Jamil (2014). Life-style adjustment, diet and exercise plans to implement recommendations of growth and obesity monitoring are available in **Additional File 4**.

Figures 8*a-k* give posture, forward bending and mild stretching photographs of LG obtained at the time of her 4^{th} checkup (eyes cropped to protect privacy of gymnast). Figure 9 gives time evolution of CDC height and mass percentiles for LG's 4 checkups.

RESULTS AND DISCUSSION

Modified-scaled percentiles of height and mass are generated based on data collected during 1998-2016 on 503 Pakistani boys (age range 3.20-12.07 *years*; mean ± standard deviation 6.21 ± 1.70 *years*; median 6.27 *years*; mode 6.68 *years*) and 1163 girls (age range 5.01-14.63 *years*; mean ± standard deviation 8.51 ± 1.85 *years*; median 8.64 *years*; mode 8.27 *years*). Parabolic curves are fitted to obtain equations for boys (6*a*)

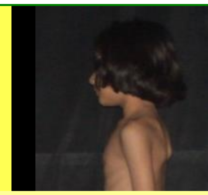
$$P_{\text{B-Scaled}}^{\text{MOD}}(h) = 1.27658744\,395554\,P_{\text{B-CDC}}(h) - 0.00276587\,44395554\,P_{\text{B-CDC}}^{2}(h)$$



Figures 8*f-k*: Posture (*f*)-(*h*) and mild stretching (*i*)-(*k*) photographs of LG taken on March 26, 2016

Table 7*a*. Growth-and-Obesity Vector-Roadmap 4.5 of LG — 1st and 2nd checkups$^{\otimes}$

Gender: Female • *Date of Birth* (*year-month-day*): 2007-08-15 • *Adult-Army-Cutoff Height*$^{\nu}$: 157.48 *cm* (19.36^{P})
Father's Height: 167.16 *cm* • *Mother's Height*: 160.16 *cm* • *Target Height*$^{\oplus}$: 157.16 *cm* (18.14^{P})

Checkup	*1st*	*2nd*
Photograph		
Scanned Signatures	*LG*	*LG*
Class and Section	II-B	II-B
Date of Checkup (*year-month-day*)	2014-11-22	2015-02-28
Age (*year-month-day*)	07-03-07	07-05-23
Age (*decimal years*)	7.27	7.54
Puberty Rating	Tanner 1	Tanner 1
Height (*cm*)	126.96	139.92
Height (*ft-in*)	4 *ft* 1.98 *in*	4 *ft* 7.09 *in*
CDC Percentile-of-Height	74.37^{P}	99.01^{P}
Modified-Scaled Percentile-of-Height	87.09^{P}	99.67^{P}
Current-Age-Army-Cutoff Height (*cm*)	118.26	119.86
Δ Height with respect to Current-Age-Army-Cutoff Height (*cm*)	+8.70	+20.06
Current-Age-Mid-Parental Height (*cm*)	118.00	119.59
Δ Height *with respect to* Current-Age-Mid-Parental Height (*cm*)	+8.96	+20.33
Estimated-Adult Height (*cm*)	167.59	180.04
Estimated-Adult Height (*ft–in*)	**5 *ft* 5.98 *in***	**5 *ft* 10.88 *in***
Modified Status (pertaining-to-height)$^{\pi}$	+7.35%	+16.74%
Descriptive Status (pertaining-to-height)	1st-Degree Tall	2nd-Degree Tall
Net Mass (*kg*)	23.66	25.69
Net Weight (*lb-oz*)	52 *lb* 2.72 *oz*	56 *lb* 10.34 *oz*
CDC Percentile-of-Net-Mass	51.31^{P}	61.58^{P}
Modified-Scaled Percentile-of-Net-Mass	81.05^{P}	87.25^{P}
Percentile-of-*BMI*-based-Optimal-Mass	77.45^{P}	91.61^{P}
BMI-based-Optimal-Mass (*kg*)	27.01	31.88
Δ Mass *with respect to* *BMI*-based-Optimal-Mass (*kg*)	–3.35	–6.19
Height-Percentile-based-Optimal Mass (*kg*)	26.37	39.12
Δ Mass *with respect to* Height-Percentile-based-Optimal-Mass (*kg*)	–2.71	–13.43
Estimated-Adult Mass (*kg*)	58.62	61.76
Estimated-Adult Weight (*lb–oz*)	129 *lb* 4.04 *oz*	136 *lb* 2.73 *oz*
Modified Status (pertaining-to-mass)$^{\pi}$	–10.28%	–19.42%
Descriptive Status (pertaining-to-mass)	2nd-Degree Wasted	2nd-Degree Wasted
Away-from-Normality Index	0.1264	0.2564
Polar Angle (*degrees*)	144.43^{o}	139.24^{o}
Extended Nutritional Status	W-EC I	W-EC I
Estimated-Adult *BMI* (*kg*/*m*^{2})	20.87	19.05
Estimated-Adult-Specific *BMI*	0.870	0.794
Build	Big	Big

$^{\otimes}$Compare with Table 8*c* of Kamal, Azeemi, Khan (2017), in particular, scaled-percentile entries; for privacy and confidentiality considerations, please see 'Compliance with Ethical Standards' near the end of paper

$^{\nu}$Details of Adult-Army-Cutoff Height for the Pakistani nationals are available in Kamal, Anasri, Sarwar, Naz (2017)

$^{\oplus}$Tanner, Goldstein, Whitehouse (1970)

$^{\pi}$Modified statuses (pertaining-to-height) and (pertaining-to-mass) were defined in Kamal, Jamil, Ansari (2018)

Table 7*b*. Growth-and-Obesity Vector-Roadmap 2.6 of LG — 3rd and 4th checkups

Checkup	*3rd*	*4th*
Photograph		
Scanned Signatures	ℒ𝒢	ℒ𝒢
Class and Section	III-B	III-B
Date of Checkup (*year-month-day*)	2015-08-22	2016-03-26
Age (*year-month-day*)	08-00-07	08-07-11
Age (*decimal years*)	8.02	8.62
Puberty Rating	Tanner 1	Tanner 1
Height (*cm*)	143.51	147.255
Height (*ft-in*)	4 *ft* 8.50 *in*	4 *ft* 9.974 *in*
CDC Percentile-of-Height	99.06P	99.06P
Modified-Scaled Percentile-of-Height	99.68P	99.68P
Current-Age-Army-Cutoff Height (*cm*)	122.53	125.556
Δ Height with respect to Current-Age-Army-Cutoff Height (*cm*)	+20.98	+21.699
Current-Age-Mid-Parental Height (*cm*)	122.25	125.270
Δ Height *with respect to* Current-Age-Mid-Parental Height (*cm*)	+21.26	+21.985
Estimated-Adult Height (*cm*)	180.44	180.423
Estimated-Adult Height (*ft–in*)	**5 *ft* 11.04 *in***	**5 *ft* 11.033 *in***
Modified Status (pertaining-to-height)	+17.13%	+17.28%
Descriptive Status (pertaining-to-height)	**2nd-Degree Tall**	**2nd-Degree Tall**
Net Mass (*kg*)	**28.21**	**29.975**
Net Weight (*lb-oz*)	62 *lb* 3.25 *oz*	66 *lb* 1.518 *oz*
CDC Percentile-of-Net-Mass	**68.54P**	**65.29P**
Modified-Scaled Percentile-of-Net-Mass	90.70P	89.15P
Percentile-of-*BMI*-based-Optimal-Mass	91.84P	91.82P
BMI-based-Optimal-Mass (*kg*)	34.20	37.209
Δ Mass *with respect to BMI*-based-Optimal-Mass (*kg*)	–5.99	–7.234
Height-Percentile-based-Optimal Mass (*kg*)	42.61	46.748
Δ Mass *with respect to* Height-Percentile-based-Optimal-Mass (*kg*)	–14.40	–16.773
Estimated-Adult Mass (*kg*)	63.88	62.886
Estimated-Adult Weight (*lb–oz*)	140 *lb* 13.64 *oz*	138 *lb* 10.624 *oz*
Modified Status (pertaining-to-mass)	–17.53%	–19.44%
Descriptive Status (pertaining-to-mass)	**2nd-Degree Wasted**	**2nd-Degree Wasted**
Away-from-Normality Index	0.2450	0.2601
Polar Angle (*degrees*)	135.66°	138.37°
Extended Nutritional Status	**W-EC I**	**W-EC I**
Estimated-Adult *BMI* (*kg/m*^{2})	19.62	19.318
Estimated-Adult-Specific *BMI*	0.817	0.805
Build	**Big**	**Big**

and girls (6*b*)

$$P^{\mathrm{MOD}}_{\mathrm{G\text{-}Scaled}}(h) = 1.66712927\,5837799\,P_{\mathrm{G\text{-}CDC}}(h) - 0.00667129\,2758378\,P^{2}_{\mathrm{G\text{-}CDC}}(h)$$

by mapping medians of height-data-CDC percentiles to modified-scaled percentile (50P), which come out to 43.21P (CDC) for boys and 34.85P (CDC) for girls. Circles are fitted to derive equations for boys (10*a*)

Table7*c*. Height-gain-target-achievement index, h_C, and mass-management-target-achievement index, μ_C, of LG at her last (fourth) checkup

At the 4th Checkup[¥]	*Measured Height*		*Measured Mass (Weight)*	
	cm	*ft-in*	*kg*	*lb-oz*
March 26, 2016	**147.255**	**4 *ft* 9.974 *in***	**29.975**	**66 *lb* 1.518 *oz***
March 26, 2016	147.273	4 *ft* 9.982 *in*	33.082 - 34.187	72 *lb* 15.127 *oz* - 75 *lb* 6.132 *oz*
Target-Achievement Index	99.988 %		90.609 % ↓	
Qualitative	h_C under -achieved		μ_C under-achieved (lesser mass outside the normal range)	

[¥] First row with dark-blue background gives measured values at the fourth checkup; following row displays targets computed from 3rd-checkup values

Table 7*d*. Month-wise height and mass (weight) targets for LG based on her last (4th) checkup, generated by Growth-and-Obesity Vector-Roadmap 2.6[£]

Date of the Most-Recent Checkup: March 26, 2016 • *Decimal Age*: = 8.61643835616 *years*
CDC Percentile-of-Height: 99.0559863049[P] • *CDC Percentile-of-Mass*: 65.2854556480[P]
Reference Percentile: 99.0559863049[P] • *Percentile of Reference-BMI-based-Optimal Mass*: 91.82448368751[P]

Target Date[σ]	*Height Target*		*Range of Mass (Weight) Target Range*	
	cm	*ft-in*	*kg*	*lb-oz*
March 26, 2016	**147.255**	**4 *ft* 9.974 *in***	**29.975**	**66 *lb* 1.518 *oz***
April 26, 2016	147.775	4 *ft* 10.179 *in*	30.800-30.933	67 *lb* 14.607 *oz* - 68 *lb* 3.304 *oz*
May 26, 2016	148.279	4 *ft* 10.377 *in*	31.583-31.841	69 *lb* 10.252 *oz* - 70 *lb* 3.358 *oz*
June 26, 2016	148.799	4 *ft* 10.582 *in*	32.377-32.977	71 *lb* 6.244 *oz* - 72 *lb* 11.445 *oz*
July 26, 2016	149.302	4 *ft* 10.780 *in*	33.362-34.340	73 *lb* 9.028 *oz* - 75 *lb* 11.498 *oz*
August 26, 2016	149.823	4 *ft* 10.985 *in*	34.508-35.709	76 *lb* 1.438 *oz* - 78 *lb* 11.800 *oz*
September 26, 2016	150.344	4 *ft* 11.190 *in*	35.630-37.044	78 *lb* 9.013 *oz* - 81 *lb* 10.914 *oz*

[£] Compare with Table 8*a* of Kamal, Azeemi, Khan (2017) — range of mass (weight) targets given instead of a single value, which was based of Growth-and-Obesity Vector-Roadmap 1.0 (Kamal, Naz, Ansari, 2016)

[σ] Dark-green row represents values at the most-recent checkup, which are taken as reference to generate 6 monthly recommendations

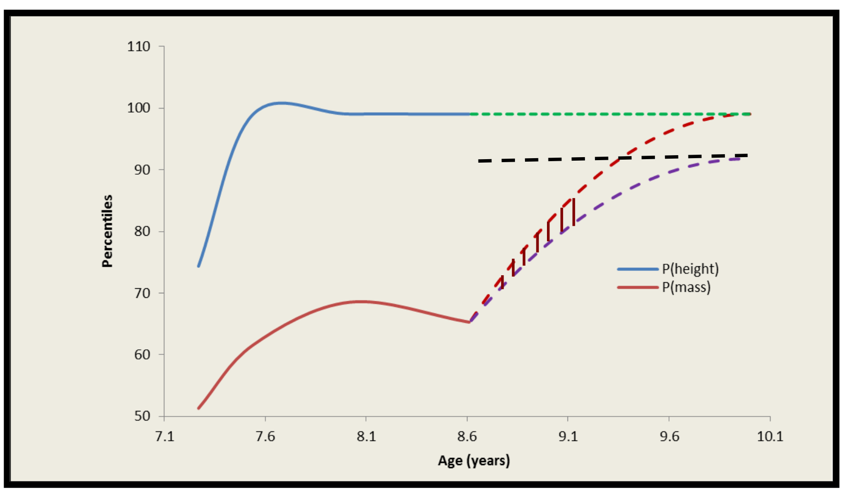


Figure 9. Time evolution of CDC height and mass percentiles of LG for her 4 checkups in the age range 7.27-8.61 *years* (navigational trajectories**:** solid curves), including the desired course-of-action (guidance trajectories**:** reference percentile — green-dashed line; reference-*BMI*-based-optimal-mass percentile — black-dashed line) and recommended intervention (control action**:** none for height-percentile curve and brown-shaded for mass-percentile curve) — compare with Figure 3*b* of Kamal, Naz, Ansari (2016)

Table 7*e*. Time slots, valid for the city of Karachi, Pakistan, for full body[δ] sun-exposure[ε] of LG during 6-*month* period following her last (4^{th}) checkup to obtain the required doses of vitamin D

Date	*Safe Period*[γ] *(a. m. – a. m.)*	*Intermittent Period*[μ] *(a. m. – a. m.)*	*Prohibited Period (a. m.- p. m.)*	*Intermittent Period (p. m. – p. m.)*	*Safe Period (p. m. – p. m.)*
APRIL					
01	6: 24 - 7: 38	7: 39 - 8: 53	8: 54 - 4: 18	4: 19 - 5: 33	5: 34 - 6: 48
15	6: 10 - 7: 26	7: 27 - 8: 43	8: 44 - 4: 20	4: 21 - 5: 37	5: 38 - 6: 54
MAY					
01	5: 56 - 7: 15	7: 16 - 8: 35	8: 36 - 4: 22	4: 23 - 5: 42	5: 43 - 7: 02
15	5: 48 - 7: 08	7: 09 - 8: 29	8: 30 - 4: 27	4: 28 - 5: 48	5: 49 - 7: 09
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

[δ]LG 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, Khan, 2018)

[γ]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)

[μ]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); complete 12-*month* entries appear in Kamal, Khan (2020*a*)

$$P^{\text{MOD}}_{\text{B-Scaled}}(\mu) = -29.0576242 + \sqrt{844.3455241 + 258.1152484\, P_{\text{B-CDC}}(\mu) - P^{2}_{\text{B-CDC}}(\mu)}$$

and girls (10*b*)

$$P^{\text{MOD}}_{\text{G-Scaled}}(\mu) = -18.00899207 + \sqrt{327.1031092 + 236.1798414\, P_{\text{G-CDC}}(\mu) - P^{2}_{\text{G-CDC}}(\mu)}$$

by mapping medians of height-data-CDC percentiles to modified-scaled percentile (50^{P}), which come out to 22.99^{P} (CDC) for boys and 19.93^{P} (CDC) for girls. Builds of a gymnast, LG, are computed (Table 8) for each of her 4 checkups, using CDC percentiles, scaled percentiles and modified-scaled percentiles.

Table 8. Build of LG determined using CDC, scaled and modified-scaled percentiles

Percentiles \ *Checkup*	*First*	*Second*	*Third*	*Fourth*
CDC[Φ]	Medium	Big	Big	Big
Scaled[φ]	Medium	Big	Big	Big
Modified-Scaled[λ]	Big	Big	Big	Big

[Φ] Table 2 of Kamal, Naz, Ansari (2016) [φ]Table 8*c* of Kamal, Azeemi, Khan (2017) [λ]Tables 4*a*, *b*

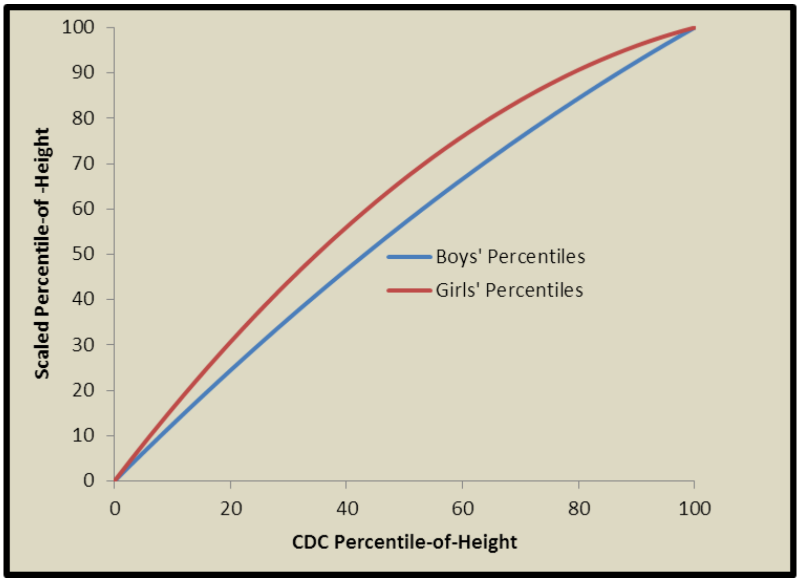


Figure 10. Modified-scaled percentiles-of-height as functions of CDC percentiles-of-height — parabola representing boys' percentiles with focus at (230.774656, 56.914686) and latus-rectum length 361.549312; parabola representing girls' percentiles with focus at (124.947993, 88.678232) and latus-rectum length 149.895985

The graphical representations of the CDC percentiles versus modified-scaled percentiles are available in Figure 10 (height percentiles) and Figure 11 (mass percentiles). CDC percentiles in the range 0 to 100^P (zero included; 100 excluded) map to scaled percentiles in the same range. In addition, it is strongly recommended that the developing countries, which do not have national data available to generate their own growth charts, may at least arrange to collect data of selected children (around 2000) from all regions to generate equations of modified-scaled percentiles for their population. Formation of trams according to build is not restricted to gymnastics, but other sports, in particular, football (Kamal, Khan, Aslam, 2020).

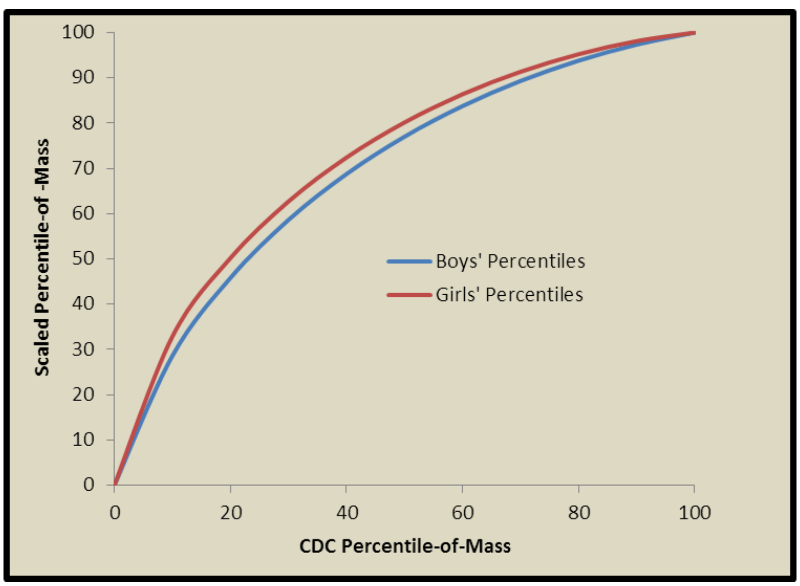


Figure 11. Modified-scaled percentiles-of-mass as functions of CDC percentiles-of-mass — circle representing boys' percentiles centered at (129.0576242, –29.0576242) and radius 132.2883815; circle representing girls' percentiles centered at (118.0899207, –18.0899207) and radius 119.4674625

RECOMMENDATIONS

In the short term, it is highly recommended to update Equations (6*a*, *b*) and (10*a*, *b*) based on further data collected at the national level. The following are long-term recommendations to establish a robust gymnastic program throughout Pakistan**:**

- Talent hunt of potential gymnasts from the age of 5-6 *years* through participation in sport academies should provide opportunities to produce national- and international-level gymnasts (Kamal, Khan, 2020*b*).
- Future formation of teams should depend, *not only*, on build, *but also*, on somatotypes. Somatotypes of elite athletes and swimmers are, already, being studied (Raković, Savanović, Stanković, Pavlović, Simeonov, Petković, 2015; Stanković, Pavlović, Petković, Raković, Puletić, 2018).
- Patchwork of CDC Growth Charts and Tables should not work for a long time, *e. g.*, extension to include percentiles in the wider range 0.01^{P}-99.99^{P} as compared to original CDC percentiles in the range 3^{P}-97^{P} (Kamal, Jamil, 2014) and scaling (Kamal, Azeemi, Khan, 2017), There is an urgent need that Government of Pakistan should take a proactive role in establishing a national-level project to construct and regularly update the Pakistani Growth Charts and Tables, which could be used to monitor growth and nutritional status of the Pakistani gymnasts.
- Height- and mass-measurement techniques for gymnasts should be enhanced to least counts of 0.001 *cm* and 0.001 *kg*, respectively, as proposed in Kamal, Naz, Ansari (2016), from the currently-available least counts of 0.005 *cm* and 0.005 *kg*, respectively (Kamal, Naz, Musafar, Ansari, 2016).
- Nutrition education of gymnasts is of utmost importance so that they can achieve optimal fitness (Gifari, Kuswari, Hutami, Ghalda, 2020).

CONCLUSION

Mathematical and statistical tools should be utilized, *not only*, to formulate guidelines to achieve sustainable optimal weight-for-height of gymnasts as well as to prevent spinal injuries, *but also*, to determine builds, which may facilitate coaches to make gymnastic teams and school administration to assign classroom sections according to build. In this paper, the authors have presented a method to generate builds of the Pakistani children based on data of a large sample of youngsters belonging to all provinces of Pakistan, which should be useful to form, *not only*, the gymnastic teams, *but also*, boxing, wrestling, football, volley ball and cricket teams. Talent hunting and proper grooming of gymnasts is a community responsibility to discover and to nurture prodigies like Nadia Elena Comăneci (Romania-United States), Ecaterina Szabo (Romania) and Mary Lou Ritten (United States).

KEY POINTS

- Percentiles for heights and masses of boys and girls need to be scaled, until that time that charts and tables are generated through reliable data collected locally.
- Modified-scaled percentiles are generated for boys and girls belonging to all provinces of Pakistan, based on height and mass data of 1666 children collected during 1998-2016.
- Parabolic curves are fitted to obtain conversion equations for height percentiles and circles for mass percentiles.
- The method is general and could be applied to populations of other countries, subject to availability of a large data sample of heights and masses.
- Builds of a gymnast for her four checkups are determined based on CDC percentiles, scaled-percentiles and modified-scaled percentiles for comparative purposes.

Table 9. Parabola properties

Equation of Parabola	*Axis*	*Equation of Directrix*	*Coördinates of Focus*	*Opening towards*
$x^2 = 4py$	y axis	$y = -p$	$(0, p)$	top
$y^2 = 4px$	x axis	$x = -p$	$(p, 0)$	right
$x^2 = -4py$	y axis	$y = p$	$(0, -p)$	bottom
$y^2 = -4px$	x axis	$x = p$	$(-p, 0)$	left

Appendix A: Equations of Parabola

The general equation of parabola may be written as

(A-1) $$y = ax^2 + bx + c.$$

Properties of parabola are summarized in Table 9. Equations of parabola given in Table 9 are derived in Additional File 3 of Kamal, Naz, Anasari (2016). Solution of the quadratic equation $ax^2 + bx + c = 0$ may be found using the quadratic formula

(A-2) $$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

The expression $b^2 - 4ac$ is termed as *discriminant*. By examining discriminant, one may conclude about the nature of real roots (qualitative analysis). If $b^2 - 4ac > 0,$ there exist two, real and distinct roots (geometrically, the parabola $y = ax^2 + bx + c$ intersects x axis at two points), whereas if $b^2 - 4ac = 0,$ the two roots are identical (quadratic expression is a complete square; geometrically, the parabola $y = ax^2 + bx + c$ is tangent to x axis). In case, $b^2 - 4ac < 0,$ no real root exists (geometrically, the parabola $y = ax^2 + bx + c$ does not intersect x axis at all).

Appendix B: Equations of Circle

The general equation of circle may be written as — center at (h, k) and radius R

(B-1) $$(x - h)^2 + (y - k)^2 = R^2$$

In polynomial form, the equation of circle is given as — center at $(-f, -g)$ and radius $\sqrt{f^2 + g^2 - c}$

(B-2) $$x^2 + y^2 + 2fx + 2gy + c = 0$$

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*Compliance with Ethical Standards***:** INSTITUTIONAL REVIEW — in the year 1998, the NGDS Pilot Project was initiated under the directives of Chancellor, University of Karachi (Governor Sindh) after going through all the formalities of 'Institutional Review Process'. The project protocols were prepared after taking into consideration North American and European, ethical and human-right standards; details may be found in Additional File 1 of Kamal, Naz, Ansari (2016).

INFORMED CONSENT — 'The Informed Consent Form' was employed for school studies, which was based on opt-in policy. This form is available at https://www.ngds-ku.org/ngds_folder/Protocols/NGDS_Form.pdf

'The SGPP Participation Form' https://www.ngds-ku.org/SGPP/SGPP_Form.pdf was used for detailed checkups in Growth-and-Imaging Laboratory, Both forms required signatures of each parent as well as the participating child. Verbal permission was obtained from the examinee(s) and the attending parent(s).

COMFORT, CONFIDENTIALITY, DIGNITY, PRIVACY AND SAFETY — Anthropometric measurements were performed giving due consideration to comfort, confidentiality, dignity, privacy, and safety of youngsters. Both acoustic as well as visual privacy was ascertained in Growth-and-Imaging Laboratory. Initials of children included in this work do not correspond to first letters in their real names (as per confidentiality standards established by the NGDS Team). Same is true about case numbers as well as pictures of children included in Growth-and-Obesity Vector-Roadmap 2.5. Comfort of examinee was given due consideration. Although, both father and mother were encouraged to attend checkups to give history and share progress, same-gender parent was preferred to be present at the unclothed physical examination in the curtained-off area for utmost comfort of the youngster. Before checkups, school-checkup-room floor was mopped and sharp objects removed from floor. Chairs/benches were checked for sharp edges of wood/metal as well as both boundaries of the mounted engineering tape were examined to safeguard abrasions and cuts of skin. In Growth-and-Imaging Laboratory, the entire floor was black-tiled, street shoes were not allowed for anyone, floor mopped with dettol (chloroxylenol)-mixed water. Thermometer bulbs, when not in use, remained dipped in dettol-mixed water. Hand washing/sanitization was mandatory at the start of each checkup. Health professionals and anthropometrists were required to remove hand-worn chains, rings and wristwatches to prevent injury to children.

DISCLOSURE AND REGRET MODEL — this model is adapted from University of Michigan Health System's Disclosure, Apology and Offer Model (Simmons, 2016), in which any wrong entry in report is communicated immediately to the parents with regrets. Mother, along with father, is invited to come and discuss the report with the principal investigator (the first author).

Additional Resources: ADDITIONAL FILE 1 https://www.ngds-ku.org/Papers/J60/Additional_File_1.pdf outlines techniques of anthropometric measurements of gymnasts, explained through step-by-step procedures, illustrated through labeled photographs.

ADDITIONAL FILE 2 https://www.ngds-ku.org/Papers/J60/Additional_File_2.pdf explains color-coding used in Growth-and-Obesity Vector-Roadmap 2.6.

ADDITIONAL FILE 3 https://www.ngds-ku.org/Papers/J60/Additional_File_3.pdf gives method of constructing Growth-and-Obesity Vector-Roadmap 2.6.

ADDITIONAL FILE 4 https://www.ngds-ku.org/Papers/J60/Additional_File_4.pdf lists lifestyle adjustment, diet and exercise plans for gymnasts.

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