ANTHROMATHEMATICS: A New Branch of Mathematics

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Throughout the course of civilization, humans have performed measurements by eye estimate, tape and calipers to describe male and female forms. Egyptian artists, over 4000 years ago, utilized a system of measurement based on the width of a human hand. *Anthromathematics* is the mathematics of human body sizes, forms, proportions and structures. The term was first used on March 22, 2010 in **the Syed Firdous Memorial Lecture on Mathematics in the Life Sciences**, delivered by the author, during the First Conference on Mathematical Sciences, as part of the Golden Jubilee Celebration of Department of Mathematics, University of Karachi. One must be familiar with the terms *anthropology* (study of human being) and *anthropometry* (measurement of human being). This century, being the century of biology, demands that the science of anthropometry should be evolved and enriched through new ideas from chemistry, engineering, health and safety, physics and, above all, mathematics. Measurement of height (a simple activity in anthropometry), for example, can be used to teach concepts from various disciplines**:**
*Biology***:** Food metabolism
*Chemistry***:** Food conversion resulting in *tissue synthesis*, the mechanism of height gain
*Engineering***:** Need of level surface, technique of mounting engineering tape
*Health and Safety***:** Nutritional-status evaluation, failure-to-grow (failure to gain height and weight) may be a signal to some physical problem, failure-to-thrive (failure to gain height, weight and achieve developmental milestones) may indicate a much deeper problem
*Physics***:** Measurement technique, reproducibility, equal weight on both feet
*Quranic Studies***:** Appointment of Tālōt as king over Israelites is mentioned in the Holy Quran (Sura 2:247); Samuel (peace be upon him) had a rod. Israelites were made aware that their king would be as tall as the length of rod (height comparison with agreed-upon standard)**:** *Kanz-ul-Imān*, p 51, Qudratullah, Lahore, 1999

The mathematical concepts, which can be learnt from this activity, are serial measurements, graph plotting, slope computation, height function as time series, adult-height prediction and comparison with cut-off height for armed-forces career (expanded from my article: From Mathematics to Technology — A Bridge Through Physics and Engineering; web address: http://www.ngds-ku.org/Papers/C70.pdf).

Let us see how mathematics can come forward to transform *anthropometry* to *anthromathematics*. Mathematics can be used in approximation of human body form by mathematical equations (*analysis* — formulae for surface area and volume of human body), studying discrete structures in the anatomy as well as the physiology of human body

Measurement of height, mass (weight), detection of scoliosis using moiré fringe topography and gait analysis using simultaneous moiré and raster recording

(*algebra* — brain death defined, mathematically, through study of group structure), discovering invariance under deformations (*topology* — spinal column deformed because of scoliosis, kyphosis or lordosis, studied by static and dynamic models), properties of numbers (*number theory* — numbers giving height, weight and other anthropometric measures) as well as analyzing inference (*logic* — upper limits of optimal weight-for-height).

To elaborate further, an *anthropometrist* takes heights, but an *anthromathematician*, not only, measures heights, but also, determines accuracy, precision and reproducibility of the techniques used while planning the session, aligns the scale, ascertains that the surface is level, checks the equipment against agreed-upon standards at the start of each session and, finally, estimates consistency of the data collected at the end of every session.

Activities of the Anthromathematics Group (http://anthromath.uok.edu.pk) of Department of Mathematics (http://math.uok.edu.pk), University of Karachi (http://www.uok.edu.pk) consist of modeling child growth and obesity as well as adult obesity. For this purpose, our group has developed techniques of measurement of height from material, available locally. Our height-measurement system may, simply, be constructed from chart sheet, engineering tape, plumb line, setsquares and transparent tape. It measures heights to accuracies more than the current-world standard (rest of the world measures heights to least counts of 0.1 *cm*, whereas our system can do this to 0.01 *cm*). Same is true for measurement of masses (to least counts of 0.01 *kg* as compared to 0.1 *kg*, available elsewhere). Growth charts, representing heights and masses (weights) of children, released by CDC (Centers for Disease Control and Prevention), USA start from 3^{rd} percentile and end at 97^{th} percentile. In the studies on Pakistani children, conducted by the NGDS Team at civilian as well as armed-forces (Pakistan Army, Pakistan Air Force, Pakistan Navy) schools, many children were found to posses heights and masses below 3^{rd} and above 97^{th} percentiles, which could not be handled by CDC Growth Charts. Our group extended these charts to include extreme percentiles (0.01^{th} 0.1^{th} 1^{st}, 99^{th}, 99.9^{th}, 99.99^{th}), published under the title "KJ-Regression Model to Evaluate Optimal masses of Extreme Cases" (http://www.ngds-ku.org/Papers/J34.pdf). In addition, our team prepared detailed training manuals for measurements of heights, masses (weights) and mid-upper-arm circumferences of children (http://www.ngds-ku.org/ngds_folder/M02.pdf), collected data on over 2500 children and trained other teams involved in child anthropometry at the

national level. A mathematical model was developed, which estimates adult-height and weight of each child and indicates whether parents are *obese* (*wasted*: lesser weight-for-height); children are *tall* (*stunted*: lesser height-for-age) and *obese* (*wasted*), associating a numerical index with each condition, in the form of percentage. The most recent expansion of this model, published in *International Journal of Biology and Biotechnology*, under the heading "Generating and Validating Growth-and-Obesity Roadmaps for the Pakistani Children" (http://www.ngds-ku.org/Papers/J35.pdf) gives month-wise recommendations to gain height, reduce or pickup mass (weight), status of nutrition (under-nutrition, over-nutrition, energy-channelization based on stunting and obesity, energy-channelization based on tallness and wasting; last 2 concepts introduced in the paper, "Stunting Induced by Wasting — Wasting Induced by Stunting**:** A Case Study" http://www.ngds-ku.org/Papers/J32.pdf) as well as classification of obesity/wasting (1^{st} degree, 2^{nd} degree, 3^{rd} degree, 4^{th} degree) with similar classification of tallness/stunting. Two other important concepts introduced by our group are *Optimal Mass* (http://www.ngds-ku.org/Papers/J29.pdf) and *Estimated-Adult BMI — BMI* stands for body-mass index, obtained by dividing mass in *kg* by square of height in *m* (http://www.ngds-ku.org/Papers/J30.pdf).

Her Excellency, **Mrs. Michelle Obama**, the First Lady of US, declared childhood obesity as national epidemic for the United States of America. Her bold step caused nutritionists, pediatricians and mathematicians throughout the world to find solutions of childhood obesity. As one would have realized, the problem was not so simple. A child is different from an adult in a way that the former is gaining height as well as managing weight, whereas the later has to deal only with the weight problem because the height of an adult does not change. Elaborate techniques of linear as well as box interpolation are needed to generate proper recommendations to gain/lose weight within the next 6 months. If a child were advised to lose more weight than necessary, the incumbent would become wasted in due course of time. On the contrary, if enough weight were not reduced, then such a child would, still, remain obese with all risks of childhood obesity applicable (http://www.ngds-ku.org/BLA/Growth_Monitoring_BLA.pdf). The honor came to mathematics community of Pakistan to provide mathematical solutions of childhood obesity. This is our gift to the United States of America.

First-Generation Solution	Presented on **Wednesday, September 4, 2013** during the First Conference on Anthromathematics under the title, "Growth-and-Obesity Roadmaps of Children"**:** http://www.ngds-ku.org/Presentations/Roadmap.pdf
Second-Generation Solution	Presented on **Thursday, September 4, 2014** during the Second Conference on Anthromathematics and Sport Mathematics under the title, "Growth-and-Obesity Enhanced-Roadmaps of Children"**:** http://www.ngds-ku.org/Presentations/Enhanced.pdf
Third-Generation Solution	To be presented on **Thursday, September 3, 2015** during the Third Conference on Anthromathematics and Sport Mathematics under the title, "Growth-and-Obesity Vector-Roadmaps of Children"**:** http://www.ngds-ku.org/Presentations/Vector.pdf (to be uploaded on Wednesday, September 2, 2015)

Static and dynamic studies of body structure are possible through posture and gait analyses of children using video, moiré and raster techniques — last two being non-

ionizing, non-invasive, non-contact, photogrammetric techniques — which provide permanent records of height (third dimension) and curvature maps, respectively, of the human subject under study. Techniques have been developed to simultaneously record moiré and raster as well as decode the information through selective-optical filtering. In addition, biometric identification systems are developed using edge-based moiré and edge-based raster (generalizations of edge-based algorithm developed at Massachusetts Institute of Technology, USA). Anthromathematics Group developed a method to determine *the Cobb angle* (quantitative indicator of scoliosis) from measurements performed on moiré topographs (and its generalization in three dimensions, *the Asr Angle* — motivated by verse of the Holy Quran**:** We, even We, created them, and strengthened "their frame". And when We will, We can replace them, Sura**:** Al-Insan 76**:**28, the terminology *Asr Angle* was first used by the author in 1982 in a paper presented during an international conference in Germany, "Determination of Degree of Correction of Spinal Deformity by Moiré Topographs" (http://www.ngds-ku.org/Papers/C23.pdf). During the year 1996, he presented 3-D models (static and dynamic) of the human spinal column. In addition, heart has been modeled as a system of standing waves and signal processing in the human brain studied in the context of covariant, generalized-coupling and covariant-generalized-coupling models (last 3 constituted author's PhD work).

On-going projects, which are being handled by the Anthromathematics Group, may be, briefly, described as:

a) Finding answer to the question**:** Are obese children, always, required to lose weight? In the studies, which we are compiling, the answer appears to come out in the negative.

b) An unbiased criterion of cutoff height, based on data of Pakistani children, for induction into the Armed Forces of Pakistan, in particular for the recruits, who are still growing (boys under the age of 21 years and girls under the age of 19 years).

c) An objective criterion to classify child players as small child, child of medium built and big child so that sport teams could be made according to heights and weights of students, just like academic sections should be made according to IQ not physical built.

In the Holy Quran, two subjects are mentioned most frequently, one is cosmos and the other human body. Indeed, human body is such a marvel of science. The author of "Bible, Quran and Science" was stunned to know that this Holy Book refers to creation of human fetus and its various stages much before it was discovered by science. In fact, this book of knowledge invites Muslims to think about the intricate machinery of their bodies. Such contemplation shall need them to appreciate the creator of this amazing system. *Anthromathematics* is one way to promote tolerance and respect for fellow human beings, the most notable creations of Almighty Allah!

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*Web address of this document***:** http://www.ngds-ku.org/Articles/A27.pdf