MANUAL FOR OBTAINING ANTHROPOMETRIC MEASUREMENTS

Version 9.11

Released 2016-04-07

Syed Arif Kamal
UNIVERSITY OF KARACHI


کراچی یونیورسٹی

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The NGDS Pilot Project
Aiming at Future of Pakistan
کراچی یونیورسٹی

Manual for Obtaining Anthropometric Measurements

OFFICIAL DOCUMENT OF THE NGDS PILOT PROJECT*

https://ngds-ku.org

Version 9.11

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This manual describes procedures for measurement of height, mass (weight) and mid-upper-arm circumference (MUAC) of children aged 3-10 *years*. Beta version was written and tested on the suggestion of Prof. Dr. Zulfiqar Ahmed Bhutta of Department of Pediatrics, the Aga Khan University Medical College, Karachi in 2003. Using this manual, the Project Director trained master anthropometrists of TAWANA PAKISTAN (2003) and students of Department of Special Education, University of Karachi (2006). The section on developmentally delayed children was added for the second training. Least counts for measurements of heights were 0.1 *cm* (1998-2011, setsquare); 0.01 *cm* (2012-2015, Vernier scale); 0.005 *cm* (Jan. 2016 to date, enhanced Vernier scale — Fig. 1*a*, *b*) and those of masses were 0.5 *kg* (1998-2011, bathroom scale); 0.01 *kg* (2012-2015, modified beam scale); 0.005 *kg* (Jan. 2016 to date, enhanced beam scale — Fig. 1*c*); children undressed except short underpants; adults in indoor clothes.

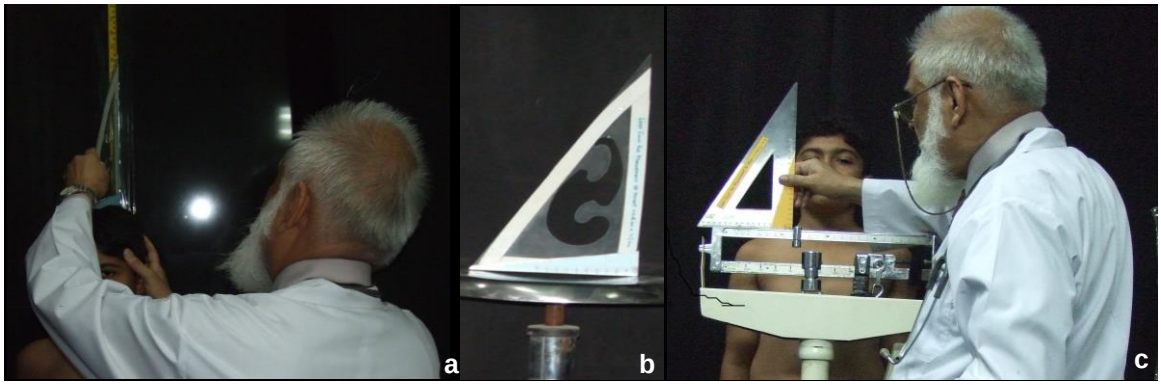

Fig. 1*a-c*. Close up of measurements of (*a*, *b*) height and (*c*) mass of a boy to least counts of 0.005 *c*m and 0.005 *kg*, respectively

UNIT ABBREVIATIONS

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

CONVERSION FACTORS

1 *in* = 2.54 *cm* • 1 *kg* = 2.205 *lb* • 1 *lb* = 16 *oz* (Bukhari and Kamal, 1987)

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1 PRELIMINARIES

1.1 Literature Survey

Anthropology, science of study of human being, became *anthropometry*, when the study involved quantitative measurements (Kamal, 2011*a*). The word *anthropometry* is a combination of *anthropo* (human) and *metron* (measure) — both having a Greek origin. This field of science aims at collecting body-measurement data of high quality using standardized examination procedures, which are standardized, and equipment, which is calibrated. Accurately and precisely collected data are fundamental for time-series modeling of anthropometric trends. Different manuals of anthropometry are available these days, some of which are prepared for specific growth studies (Carter, 2002; CDC, 2007). The manual at hand was, originally, prepared for trainings of TAWANA PAKISTAN and Department of Special Education, University of Karachi for children studying in pre-primary and primary school (ages 3-10 *years*). Since 2010, it is used, routinely, as a lab manual for students of Department of Mathematics, University of Karachi. This manual acts as the master document of the NGDS Pilot Project.

Fig. 2. Child signing the informed consent form

1.2 Sample Size

If the measurement involves testing of a hypothesis, proper sample size must be calculated according to the confidence interval chosen *before* starting the survey. Failure to do so may result in collection of data, which could be considered *statistically not significant*.

1.3 Informed Consent

Even for a simple measurement, *e. g.*, height, weight, mid-upper-arm circumference (MUAC), informed consent (Fig. 2) must be obtained as per applicable human-right protocol in the region. If the child is not in a life-threatening situation, it is better to follow *opt-in policy* (measurement performed *only* on those children, whose parents send in the filled in

and the signed slips). Consent must be *valid* (*i. e.*, the patient must be adult, free, in full senses; in case of a minor, the consent of custodial parent or guardian must be sought in addition to verbal consent of child above the age of 7 *years*) and *informed* (*i. e.*, the patient must be given sufficient information in relevant language using appropriate vocabulary accompanied by pictures and videos, in particular, for parents, who do not have the necessary medical background) — see the note added on page 17 (on April 23, 2024) to ensure transparency. Failure to adhere to this policy may result in denial of publication in a reputable journal.

1.4 Recording of Data

The following information must be entered for each anthropometric measurement (height, weight, MUAC). Information should be entered using pen on data sheets and later on transferred in computer.

1.4.1	Name and signatures of measurer	1.4.5	Time of measurement
1.4.2	Name of assistant (helper)	1.4.6	Place of measurement
1.4.3	Name of chaperon — *cf.* 1.5	1.4.7	Dress code (description of clothing worn) — *cf.* 1.10
1.4.4	Date of measurement	1.4.8	Behavior code — *cf.* 1.11

1.5 Chaperon

It is recommended to have a *chaperon* (a person of same gender as the patient), in case a measurer of opposite gender is collecting data on peripubertal (children about to enter puberty, characterized by leveling off of height curve) or pubertal children — not required if a parent is present. The purpose is to protect the health-care provider as well as the patient by minimizing risks of false allegations of misconduct, misinterpretations of actions as inappropriate or a simple misunderstanding. Examination of a minor (youngster below the age of 18 *years*) should, always, be conducted in the presence of at least one parent or schoolteacher.

1.6 Safety

Laboratory should to be made childproof, as children tend to use ordinary objects (pins, staples, *etc*.) for play and mischief. Before the start of every session, all equipment is checked for performance and safety. All surfaces, with which the children would come in contact, including floor, are checked for rough edges and sharp objects. The measurer should remove all hand-worn accessories (bangles, watch, ring, chain, bracelet, *etc.*) to prevent skin abrasions to child's skin during anthropometry. Of course, measurer's nails should be cut and trimmed. Look at sources of hazard/injury listed for each type of measurement.

1.7 Privacy

Acoustic and visual privacy of the participants should be respected. Examination rooms, which are, also, used for history taking, should have acoustic privacy, so that other patients (or unrelated persons) do not hear the conversation among doctor, nurse, patient and patient's family (if accompanied by patient). This cannot be accomplished in a curtained consultation area, which would afford only visual privacy. Of course, there should be curtain covering the examination area, which could be used for intimate examinations.

1.8 Confidentiality

Only the patient, or the patient's parents (in case of a minor) or legal guardians (of a patient not capable of making rational decisions about self) are given access to medical records. Data, reported in research papers, reports or presentations, are to be in collective form, without identifying individual patients, to protect confidentiality. On the other hand, all collected data stored in the database must be identifiable by patient's name and case number, to protect mishandling of information. No data collected should be discarded at any stage, as it is needed for research and becomes a trust of the society. Even when it seems that the data are outdated for research purposes, the data still cannot be destroyed, but put in achieves in the form of compressed files[1]. In case presentations, family labels and children's initials should not correspond to first letters in actual names. It needs to be maintained about case numbers appearing in the main and the auxiliary research documents. They may not be the ones used to classify patient record and appear on the reports issued to patients. However, there should be a mechanism established, through which the core researchers can, immediately, track the actual cases from the coded numbers included in documents.

1.9 Comfort

As undressing is essential for measurements of children (Kgamphe, 2009; Nissinen *et al.*, 1994; Prahl-Andersen, 1979; Waaler, 1983), it is recommended that same-gender measurer performs these tasks. For parents as well as peripubertal and pubertal children, it is preferable that same-gender physician's assistant takes history. Even in mild temperatures, fans are not switched on during the checkups, as the children are

unclothed for procedures. A social scientist or a teacher should be present during all measurement sessions.

1.10 Hygiene

Since the children would be barefoot for measurements, floor should be mopped with dettol-added water — generic name of 'dettol' is chloroxylonol. Ideally, street shoes should not be allowed in the measurement area for the lab staff as well as the visiting family. Sleepers may be provided at the lab entrance to be put on before proceeding to the measurement area (since February 2016 this policy is implemented in SF Growth-and-Imaging Laboratory). The measurer should wash and disinfect hands prior to start of session. Gloves should be worn by those handling the youngster, if the examinee shows signs of skin infections.

1.11 Dress Code

The amount of clothing present on a child effects measurements, examinations and observations. Therefore, a dress code is proposed for every measurement, examination and observation (Kamal, 1998; 2002; Kamal *et al.*, 2002; 2004). The dress code is a fraction, whose numerator (denominator) represents amount of clothing superior (inferior) to transverse plane passing through the naval. Zero (0) represents the absence of clothing and three (3) the maximum amount of clothing. The following key may serve as guideline**:**

3/• Fully dressed above waist	•/3 Fully dressed below waist
2/• Cap, hat, *dupatta*[2], scarf, *V*[3] or other head covering removed; dressed in shirt or *kameez*[4]	•/2 Shoes (trainers[5], sneakers[6]) and socks removed; dressed in trousers (pants[7]), stockings or *shalwar*[8]
1/• Undressed to undershirt	•/1 Undressed to shorts
0/• Stripped to waist	•/0 Completely undressed below waist

1.11.1 *Examples of Dress Codes*

A number in decimals would represent amount of clothing between 2 consecutive whole numbers. For example, a code 0/0.5, would indicate that the child is undressed to short underpants (briefs or panties), all clothing above the waist removed (a practical clothing choice for anthropometric measurements of children), a dress code 0.5/0.5 may be indicative of short upper undergarment kept on during the measurement, whereas a code 0/0 would mean the child is completely undressed, no covering of any kind. It should be noted that 0/0 is 'indeterminate', in the mathematical framework, meaning a specific value cannot be assigned to this expression. However, in the context of anthromathematics (Kamal, 2010), this expression corresponds to a very specific concept. Sometimes, very young children refuse to remove leggings, socks or shoes, and the measurement has to be taken with these articles of clothing on. A dress code should indicate these non-standard procedures; *e. g.*, 'L' following a dress code may represent presence of leggings, 'S' stockings, 'So' socks (if not removed), 'Sh' shoes (worn during measurement) and 'G' gown (if put on). For the measurement of parents, one may notice a code 1.5/1.5 (half-sleeved blouse, skirt), 2/2 (shirt, trousers) or (*kameez*, *shalwar* with head uncovered and *V*/*dupatta* removed), 2.5/2 (*kameez*, *V* or *dupatta*, *shalwar*), 3/3 (*abaya* or *burqa*[9] without head covering) 3.5/3 (*abaya* or *burqa* with head covering), *etc*. Every examiner must, however, set the code according to the environment and the style of clothing worn at the measurement setting. The codes used should be explained at the beginning of a report**.**

1.11.2 *Optimal, Recommended and Actual Dress Codes*

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

1.11.3 *Necessity of Undressing for Children's Anthropometry*

For data collected to be reported in MSc-project reports, MS/MPhil theses, PhD dissertations, national/international-conference presentations and papers published in peer-reviewed journals, it is very important that arrangements should be made so that anthropometric measuremts should be taken after children have been appropriately undressed for the following reasons**:**

1.11.3.1 To ascertain maintenance of proper posture during various anthropometric procedures, as explained in 1.11.3.1.1 to 1.11.3.1.3 — Additional File of Kamal *et.al.* (2016*b*) contains definitions of anatomical axes and planes**:**

1.11.3.1.1 *Height Measurement***:** Non-flexing of knees and elbows; attention position; weight equally

distributed on both feet; head in the Frankfurt plane.

1.11.3.1.2 *Mass Measurement***:** Non-flexing of knees and elbows; stand-at-ease position; weight equally distributed on both feet; head straight.

1.11.3.1.3 *MUAC Measurement***:** Thigh and shin of each leg perpendicular to each other; hand flexed at 90^{o} at the elbow joint; thighs and upper torso at right angle; head straight

1.11.3.2 To ascertain proper inhalation during all three measurements.

1.11.3.3 To record net mass without mass of clothing.

1.12 Behavior Code

The behavioral state may have a numerical value 0 (relaxed and coöperative), 1 (timid and shy, but co-öperative) and 2 (resistant and nagging).

1.12.1 *Optimal, Recommended and Actual Behavior Codes*

The optimal value for all the measurements is 0 (Kamal *et al.*, 2002; 2004). In the procedures for measurement of height, weight and mid-upper-arm circumference (MUAC), the maximum numerical value of behavior code, '*b*', is given for which this procedure is permitted, termed as recommended behavior code. The form, on which anthropometric measurement is recorded, must have a column to enter the actual behavior code, '*B*', the child was in at the time of that particular procedure. Note down if the procedure, itself, changed the behavior code (Kamal, 1998; 2002). In order to perform measurements in the behavior code 0, it is suggested to brief about and demonstrate the procedures, beforehand.

1.13 Measurements of Developmentally-Delayed Children

A developmentally-delayed child may not be able to stand for measurement of height and weight or sit on a stool for measurement of mid-upper-arm circumference (MUAC). If a posture approximating the standing posture is achieved, stature should be measured by the methods given below. Record the limitations of measurement (with a photograph of child's posture, if possible) on the chart. If the child is unable to stand at all, measure recumbent length, and make a note on the chart. Similar adaptation may be needed for measurement of mass (weight). A child reluctant/unable to stand alone on the scale, may be weighed along with a parent. The child could, later, be held by another person, and weight of parent recorded. Difference of the 2 readings should give the weight of child.

1.13.1 *Uniformity of Protocols*

Follow the same techniques and protocols during successive measurements. Understanding instructions, compliance and coöperation may be issues with the child affected with Down's syndrome.

2 MEASUREMENT OF STANDING HEIGHT (STATURE)

This is one of the essential measurements during childhood and adolescence, indicating tissue synthesis. Failure to gain height in childhood is the first indicator that body systems are not working properly. Hence, the problem needs to be addressed at an early stage. If one of the children is stunted (short-for-age) and the other may have normal height, there may be a hormonal deficiency or scoliosis may be suspected. Excessively tall children are at a higher risk to develop scoliosis (Kamal, 2012; Kamal *et al.*, 2013*c*). There are, also, indications that wasting is induced by stunting (Kamal *et al.*, 2014*c*).

2.1 Materials Required (in alphabetical order)

2.1.1 Box[10]
2.1.2 Chair (with wooden base)[11]
2.1.3 Chart sheet
2.1.4 Disposable combs
2.1.5 Eraser
2.1.6 Glue (strong)
2.1.7 Gloves
2.1.8 Magnifying glass
2.1.9 Mirrors (strip + wall mounted)
2.1.9 Mounting tape
2.1.10 Pencil
2.1.11 Plumb line[12]
2.1.12 Setsquares
2.1.13 Spirit level[13]
2.1.14 Steel measuring tape
2.1.15 Torch
2.1.16 Transparent tape
2.1.17 Wooden board

2.2 Least Count[14]

For the wall-mounted-height-measurement system developed and implemented by the NGDS Team (described below), the least count (Kamal, 2009) is 0.1 *cm*. Since 2012, least count of height-measurement system in SF Growth-and-Imaging Laboratory is 0.01 *cm* (Kamal, 2010*a*). This has been accomplished by mounting Vernier scale on the setsquare used to measure height. Since early 2016, the NGDS team upgraded

Fig. 3*a-d*. Positioning of (*a*) feet and (*b*) head for stature determination (setsquare placement); heights of (*c*) a boy and (*d*) a girl measured in SF Growth-and-Imaging Laboratory

height measurement to least count of 0.005 *cm* (Kamal *et al.*, 2016*a*).

2.3 Performance Checking (Calibration[15])

At the start of each daily height-measurement session, a standard cylinder must be used to check if the mounted scale is working properly. The method is to measure length of a cylinder using Vernier calipers and then take the reading through the mounted scale (Kamal, 2009).

2.4 Procedures

2.4.1 To be measured in the first half before 12 noon.

2.4.2 Check the level of floor using spirit level. If the floor is not level (inclined), along the line (formed by joining heels of the standing child), either shift the place or use a wooden board, which is adjusted to horizontal level by keeping paper supports under the corners.

2.4.3 Check the angle made by the wall with the floor using a setsquare. If the wall is not vertical, try to find a vertical wall or fix a wooden board vertically on the wall.

2.4.4 Paste the chart sheet on wall or door with the help of mounting tape. A better option is to use strong glue to stick the chart sheet to the wall.

2.4.5 Place the steel measuring tape vertically on the center of chart sheet from the floor up to the two-meter length with the help of transparent tape very firmly. In order to avoid cuts, gloves should be worn during mounting process.

2.4.6 Check the vertical alignment and parallax errors using plumb line and mirror, respectively.

2.4.7 Ask the child to remove everything (head covering, undershirt/vest, shoes, socks and accessories, which include bangles, hair-band/hair-clips, pony, rings) except short underpants — dress code 0/0.5 (Fig. 3*a-d*). Box should be provided to child to keep removed accessories for safekeeping. Undressing is mandatory for measurement of height.

2.4.8 Using a (disposable) comb part hair leaving gap in the middle, where the setsquare is placed (comb not to be shared by children to avoid transmission of infection).

2.4.9 The child should stand erect in attention position (military parade) with heals together and touching the wall, buttocks and upper part of the back in contact with the vertical wall.

2.4.10 Hands should be straight and open, palms touching the thighs.

2.4.11 Centralize the position of child with the help of a setsquare passing between both feet and aligned to the measuring tape on the wall as well as the horizontal line drawn on floor (Fig. 3*a*).

2.4.12 Chin should be parallel to floor and head in Frankfurt plane (examiner should hold a pencil in front of the face of child; instruct the child to look at the pencil). Knees and elbows should not be flexed.

2.4.13 A better option is to mount a mirror facing the examinee, and ask the child to look into own eyes.

2.4.14 Ask the child to trap maximum air and measure height with the help of a setsquare by touching (not pressing) it over the head the other side aligned with the measuring tape mounted on wall (for taller individuals the measurer should stand on a wooden chair to bring eyes in line with head of the person, whose height is being measured). The setsquare should be placed so that its surface lies in sagittal plane passing through nose. To make sure this is the case, hold another setsquare parallel to transverse plane, one side aligned with the sagittal-plane setsquare, the other with the chart sheet (Fig. 3*b*).

2.4.15 Note height to least count of 0.005 *cm* using setsquares with enhanced-Vernier scale mounted on edge — 20 Vernier-scale graduations coinciding with 19 main-scale graduations (Fig. 3*c, d*)[16].

2.4.16 Ask the child to step away from the wall.
2.4.17 Use a magnifier/torch if you need one.

2.5 Sources of Hazard/Injury

2.5.1 Sharp edges on both sides of steel tape not properly covered by transparent tape, resulting in body abrasion/cut (check that both sides of the engineering tape are properly covered with transparent tape at the start of each session before the process of calibration).
2.5.2 Top of steel tape not properly mounted on the wall, could come out peeling off the steel tape and causing injury to the child.
2.5.3 Chart sheet not mounted firmly on the wall, might come out bringing steel tape along and causing injury.
2.5.4 Sharp edges of setsquare going in eyes or ears.

2.6 Sources of Error

2.6.1 Carpet (in faculty offices)
2.6.2 Measuring time not same (morning and evening)
2.6.3 Level of surface in laboratory
2.6.4 Hair on the head
2.6.5 Scarf (if not taken off)
2.6.6 Leggings, socks and shoes (if not removed)
2.6.7 Breathing (not complete inhaling)
2.6.8 Heels lifted up
2.6.9 Toes lifted up
2.6.10 Uneven floor (mud), during field studies
2.6.11 Not putting equal weight on both feet
2.6.12 Child holding on to something
2.6.13 Parallax error
2.6.14 Head not straight (tilted forward or backward)
2.6.15 Shrinking neck muscles
2.6.16 Standing height is lesser as compared to recumbent length
2.6.17 Child flexing knees/elbows
2.6.18 Improper use of set square
2.6.19 Feet with mud
2.6.20 Weak muscles of hips and legs
2.6.21 Child not standing still
2.6.22 Child not looking straight
2.6.23 Height measured after strenuous exercise

2.7 Technical Note

Beam setup for measuring height, provided in most weighing scales of beam type, is inappropriate for measurement of standing height. Standing-height machine or setsquares (method described above) should be used for measurements. If setsquares are not available, a book may be used. However, use of book may introduce alignment errors (Kamal, 1982*a*).

	d	*b*
3 MEASUREMENT OF MASS (WEIGHT)	**0/0.5 (0/0)**	**1 (0)**

Mass is another essential measurement having significance in all age ranges. Failure to gain mass (weight)/rapid loss of weight in childhood may signal a deeper problem, requiring a complete physical and psychological examination. Both underweight and overweight conditions in childhood have serious ramifications, when it comes to quality of life in adulthood and old age. There are, also, indications that stunting is induced by wasting (Kamal *et al.*, 2014*c*).

3.1 Materials Required (in alphabetical order)

3.1.1 Beam scale/Bathroom scale
3.1.2 Box[10]
3.1.3 Eraser
3.1.4 Magnifying glass
3.1.5 Pencil
3.1.6 Setsquares
3.1.7 Spirit level
3.1.8 Standard mass of 2 *kg*
3.1.9 Torch
3.1.10 Wooden board

3.2 Least Count

For bathroom and beam scales, the least counts are 0.5 *kg* and 0.1 *kg*, respectively. For serious studies, involving growth disorders, bathroom scale is inappropriate. Since 2012, least count of mass-measurement system in SF Growth-and-Imaging Laboratory is 0.01 *kg* (Kamal, 2010*a*). This has been accomplished by mounting a Vernier scale on a setsquare and aligning it with the cylinder in the upper beam. Since early 2016, the NGDS team upgraded mass measurement to least count of 0.005 *kg* (Kamal *et al.*, 2016*a*).

3.3 Performance Checking (Calibration)

At the start of each daily mass-measurement session, a standard 2-*kg* mass must be used to check if the beam scale is working properly. This standard mass may not be sensitive enough (Kamal, 2009) to give reading on the bathroom scale.

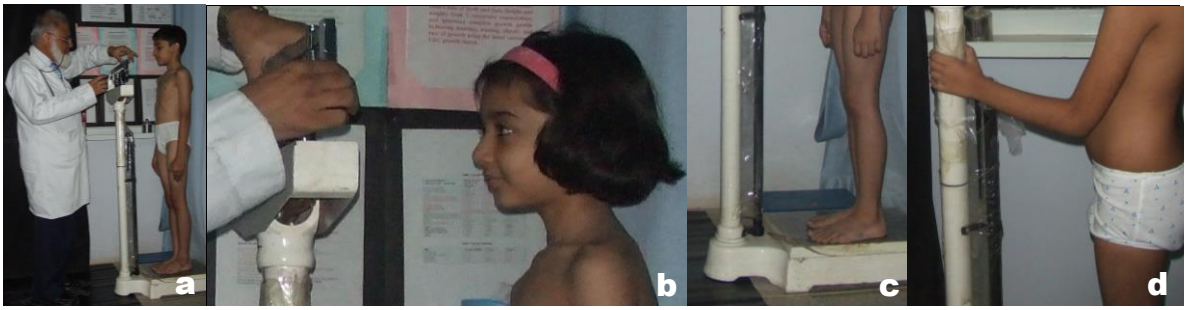

Fig. 4*a-d*. Recording of (*a*) mass of a boy and common errors in measurement process — (*b*) hair-band not removed; (*c*) feet not positioned correctly and (*d*) child holding on to beam scale

3.4 Procedures

3.4.1 Measurement should be done in the first half before 12 noon.

3.4.2 Select a suitable place to put down the bathroom or the beam scale — a wooden board or a clean-cemented floor. Check the level of this surface using a spirit level. If the surface is not level (inclined), along the line (formed by joining heels of standing child), identify another place or reorient the weighing machine.

3.4.3 Place the weighing machine on this surface.

3.4.4 Check the level of weighing machine, along the line mentioned in 3.4.2, with the help of spirit level placing it over the center of machine.

3.4.5 Make sure that the weighing machine reading is ZERO. If that is not possible, note down the zero error and subtract it from each reading.

3.4.6 Place a standard mass of 2 *kg* to check if the beam scale is working properly.

3.4.7 Ask the child to take off everything (cap/scarf, undershirt/vest, shoes, socks and accessories, which include bangles, hair-band/hair-clips, pony, rings) except briefs or panties — dress code 0/0.5 (Fig. 4*a-d*). Disrobing is essential for recording of mass of child.

3.4.8 Ask the child to step on the weighing machine in stand-at-ease position (military parade), both feet parallel (slight gap between them) and look straight. Knees and elbows should not be flexed.

3.4.9 Hold a pencil at eye level, in front of nose and ask the child to look at the pencil.

3.4.10 Ask the child to breathe in deep and hold breath.

3.4.11 Record mass of child to least count of 0.005 *kg* using setsquares with enhanced-Vernier scale mounted on edge, if using the beam scale[17]. Record to an accuracy of 0.5 *kg* with the bathroom scale.

3.4.12 The recording should be done with the assistance of a social scientist or a teacher.

3.5 Sources of Hazard/Injury

3.5.1 Child stepping unevenly on the bathroom scale, resulting in overturning of the scale.

3.5.2 Child playing around the beam scale, resulting in fall of the scale.

3.5.3 Sharp edges of setsquare going in eyes or ears.

3.6 Sources of Error

Figures 3*b-d* show common sources of error in measurement of mass. Some are listed below**:**

3.6.1 Heavy and light clothing during successive measurements of adults

3.6.2 Different styles of clothing during successive measurements of adults

3.6.3 Scarf (if not taken off)

3.6.4 Leggings, socks and shoes, if not removed

3.6.5 Shaking child

3.6.6 Zero error

3.6.7 Unequal weight on both feet

3.6.8 Child holding on to something

3.6.9 Breathing (not complete breath in)

3.6.10 Heels up and down

3.6.11 Flexing of knees and/or elbows

3.6.12 Recording at different times of the day

3.6.13 Wet body after bath

3.6.14 Body not clean

3.6.15 Pockets holding heavy things

3.6.16 Measuring before and after elimination

3.6.17 Looking down to read own weight

3.6.18 Measuring before and after heavy meal intake

3.6.19 After disturbed sleep

3.6.20 Weight of watch, ornament and eye glasses (if not removed)

3.6.21 Level of surface, on which machine is placed

3.7 Net Mass and Clothing Correction

Net mass is defined as mass recorded when the subject is not wearing any clothing. This is the mass mentioned in growth tables and charts. Often, in field studies, mass is recorded with the subject wearing

Table 1. Recommended clothing correction for measurement of children

Dress Code	*Description of Attire*	*Clothing Correction (kg)*
0/2	Stripped to waist, wearing trousers (Waaler, 1983)	0.1
0/1	Stripped to waist, wearing shorts	0.05
0/0.5	Stripped to waist, wearing briefs/panties (Kamal *et al.*, 2011*a*)	0
0/0	Completely undressed, no clothing present	0

some clothing (children just underwear, absolutely nothing above waist; adults indoor clothing). This mass is termed as *gross mass*. Net mass is obtained from gross mass by subtracting a suitable clothing correction. Table 1 suggests clothing corrections for different articles of clothing left on a child. The author proposed a method (although, time consuming and not practical) through which net mass could be determined without asking the subject to remove all clothes (Kamal, 2010*a*). $\mu = \mu_a + \mu_b - \mu_{a+b}$ [18] could be used to compute net mass (mass with zero clothing on) without asking the subject to disrobe completely (μ is net mass, μ_a mass with one set of clothing worn, μ_b mass with the other set of clothing worn and μ_{a+b} mass with both sets of clothing worn).

3.8 Technical Note

Measurement taken using a bathroom scale gives weight (measurement performed on the basis of Hooke's law), the machine is *wrongly calibrated*[15] (Kamal, 2009) in *kilograms* (a unit of mass) — this point is well illustrated by the fact that an object showing a weight equivalent to a reading of 1 *kg* on earth shall show a weight equivalent to a reading of 1/6 *kg* on moon; whereas the measurement performed using a beam scale gives mass (comparison with the standard mass, using the principle of lever). Further, in studies involving growth disorders measurements taken in indoor clothing or on bathroom scale do not make any sense. Bathroom scale has a least count of 0.5 *kg*, whereas international standards call for measurement to an accuracy of at least 0.1 *kg*.

d *b*
0/0.5 **1 (0)**

4 MEASUREMENT OF MID-UPPER-ARM CIRCUMFERENCE (MUAC)

MUAC is an indicator of state of nutrition in children and can be obtained easily during field studies. An unequal MUAC on both arms may indicate presence of trunk deformities/wrong exercise routine.

4.1 Materials Required (in alphabetical order)

4.1.1 Box[10]
4.1.2 Eraser
4.1.3 Magnifying glass
4.1.4 Micrometer screw gauge
4.1.5 Mirror strip
4.1.5 Pencil
4.1.6 Skin marker
4.1.7 Tailor's tape
4.1.8 Torch
4.1.9 Vernier calipers

4.2 Least Count

For tailor's tape, the least count is 0.1 *cm*. This procedure is prone to greater variation among different readings because pressure applied may vary (Figures 4*a-c*).

4.3 Performance Checking (Calibration)

At the start of each MUAC-measurement session, a standard cylinder (with diameter measured using

Fig. 5*a-c*. Positioning of (*a*) feet on wooden planks, (*b*) determining separation of acromial and radial landmarks as well as (*c*) measuring MUAC

Vernier calipers) must be used to measure circumference of the curved surface, to ensure that the tailor's tape is working properly. The measured circumference (by tape) should agree with the computed value given by the product of *measured diameter* and π — an irrational number having value of 3.14159…..[19].

4.4 Procedures

4.4.1 The measurement should be done in the first half before 12 noon, on both the right-upper and the left-upper arms (for the purpose of comparison of both values), with the child completely undressed except short underpants — necessary to visualize proper posture.

4.4.2 Check the level of floor using spirit level, where stool is to be placed. If the floor is not level (inclined), either shift the place or use a wooden board, which is adjusted to horizontal level by keeping paper supports under its corners.

4.4.3 Ask the child to sit on stool and place both hands prone[20] on thighs, arms aligned with the upper torso and breathe in to trap maximum air.

4.4.4 If the child's feet do not touch the floor, place wooden planks on the floor so that the feet are resting on the plank and making an angle of 90^o with shin (Fig. 5*a*). In case legs are long, with the result that thigh and shin are making an acute (less than 90^o) angle, when the child is sitting on the stool, measurement cannot be obtained. The stool must be raised so that the above-mentioned angle becomes exactly 90^o and feet rest on the floor.

4.4.5 Locate the acromial and the radial landmarks.

4.4.6 Label these landmarks with a skin marker (this activity dropped after initial practice).

4.4.7 Measure, carefully, distance between the two landmarks with the help of tailor's tape (Fig. 5*b*).

4.4.8 Divide the above reading by 2 to locate the midpoint between the two landmarks.

4.4.9 Label the midpoint with a marker, *e. g.*, if the reading is 30 *cm* then divide by 2 to get 15 *cm* (this activity dropped after the initial practice).

4.4.10 Measure the circumference at the marked midpoint with the help of tailor's tape in centimeters. In order to make sure that the tape is parallel to the horizontal plane, a mirror strip is mounted on the wall behind the child to visualize the back side of tape.

4.4.11

4.4.12 Do not stretch the tape (Fig. 5*c*).

4.5 Source of Hazard/Injury

4.5.1 Pressing too hard on the skin of arm and blocking circulation.

4.6 Sources of Error

4.6.1 Not measuring exactly at the center
4.6.2 Stretching the tailor tape
4.6.3 Measuring after exercise
4.6.4 Measuring after IV infusion
4.6.5 Not inhaling completely
4.6.6 Swelling due to allergy and inflammation
4.6.7 Position of elbows and knees (not making 90^o)
4.6.8 Child holding on to something in hands
4.6.9 Tailor's tape not parallel to horizontal plane[21]

4.7 Technical Note

If the child is wearing a long-sleeved shirt or a sweatshirt, which cannot be removed to take measurement on bare skin (measurement by rolling up the shirt is not acceptable as acromial landmark is non-unique in this non-standard procedure), the measurement is taken over shirt and converted to bare-skin circumference using the following formulae (Kamal, 1986)**:**

(1*a, b*) $g = G - 2\pi a$ (tight-fitting clothing); $g = G' + 2a(1-\pi)$ (loose-fitting clothing)

where, g MUAC on bare skin
a Thickness of clothing (obtained using micrometer screw gauge)
G MUAC on tight-fitting clothing
G' MUAC on loose-fitting clothing, not including two layers, held in front to fix things

5 CONCLUDING REMARKS

For a model of child growth (Kamal and Jamil, 2012; Kamal *et al.*, 2004; 2011*a*; 2013*e*; 2014*b*; 2015*b*) to provide clinically useful information (Kamal, 2014), it is imperative to have a standard protocol for measurement — easy-to-use equipments, easy-to-implement procedures, reliable and reproducible (Kamal *et al.*, 2013*f*). The three types of errors, imprecision (intra- and inter-observer variation — stability and objectivity),

Biology	The metabolism of food
Chemistry	The process of conversion of food resulting in *tissue synthesis* (the phenomenon of height gain)
Engineering	Level surface needed, mounting of engineering tape (vertical mounting checked by plumb line)
Health and Safety	Evaluating nutritional status, failure to gain height may be a signal to some physical problem (failure-to-grow); failure to gain height and achieve developmental milestones may indicate a much deeper problem (failure-to-thrive) — pediatrician should look for indications of abuse (neglect, peer pressure/bullying, verbal, physical, sexual) in this situation (Kamal, 2011*d*)
Mathematics	Significance of serial measurements, plotting of graph, computation of slope, time-series concept, prediction of adult height, comparison with cut-off height for armed-forces career
Physics	Techniques of measurements, achieving reproducibility, applying equal weight on both feet
Quranic Studies	The Holy Quran (sacred book of Muslims) mentions appointment of Tālōt as king over Israelites (verse 247, chapter 2, *Suratul-Baqara*). It is mentioned that Samuel (peace be upon him) had a rod. It was told to Israelites that their king would be as tall as the length of rod — comparison of height with agreed-upon standard (Khan and Naeemuddin, 1999)

Fig. 6. Pedagogical and andragogical opportunities offered by the activity of measurement of height

inaccuracy (instrument error, actually systematic error) and undependability (non-nutritional factors affecting measurement reproducibility, *e. g.*, variation of height and weight during the day) should be minimized (Ulijaszek, 1997). Only measurers with documented reproducibility should perform measurements, which are reported in research papers. Establishment of SOPs (standard operating procedures) would allow researchers in different parts of the world to compare their findings (Onis *et al.*, 2004) and update growth charts (Karlberg *et al.*, 1999). The anthropometrists should be trained to spot under-nutrition (Kamal *et al.*, 2014*c*), acute malnutrition (Kamal, 2015*b*), trunk deformities (Kamal *et al.*, 2013*c*; 2014*a*; 2015*a*) and signs of abuse (Kamal, 2011*d*; Kamal and Khan, 2014), as they'll have a chance to see the children, undressed. The parents should appreciate the importance of accurate and precise (Kamal, 2009) measurements — there is, also, a need to modify anthropometric instruments to keep pace with the improvement in protocols (Kamal, 1982*b*). Those, who have custody of the child, should take a proactive role in ensuring that their child should be measured according to procedures, accepted internationally (Kamal, 2011*c*). Of course, the parents would take interest in the measurement processes, if they have support system available, which could guide them at every stage to take care of the health needs of their children and provide easy-to-implement solutions for their children to gain height (Kamal, 2013*a*; Kamal *et al.*, 2013*b*), manage weight according to height (Kamal, 2013*b*; 2015*a*; *c*; Kamal and Jamil, 2014; Kamal *et al.*, 2013*d*) and overcome vitamin-D deficiency (Kamal, 2013*c*; Kamal *et al.*, 2013*a*) by lifestyle adjustment, diet and exercise plans (Kamal and Khan, 2013; 2014; 2015). Measurements of heights and masses (weights) could offer learning

Biology	The metabolism of food
Chemistry	The process of food conversion resulting in gaining energy, sweating
Engineering	Need of level surface, checking if the weighing machine, itself, is level
Health and Safety	Rapid loss of weight signals physical problems, unutilized food results in fat deposit, contributing to obesity
Mathematics	Significance of serial measurements, plotting of graph, computation of slope, concept of time series, prediction of adult mass (weight), optimal mass-for-height, net-mass computation from gross mass (Kamal, 2010*a*) — net mass is defined as mass with zero clothing on, gross mass is the mass recorded in indoor clothes
Physics	Measurement techniques, reproducibility of measurers, exertion of equal weight on both feet
Quranic Studies	Maintaining optimal weight-for-height is encouraged in the Holy Quran (verse 29, chapter 17, *Surah Bani-Israel* or *Suratul-Asra*) by stating that one should exercise discretion in spending, neither to spend too much like burning candles at both ends nor to become stingy (Kamal and Jamil, 2012)

Fig. 7. Pedagogical and andragogical opportunities offered by the activity of measurement of mass

Biology	The metabolism of food
Chemistry	The process of food conversion resulting in proper muscle and fat development
Engineering	Need of level surface, checking if the stool, itself, is level
Health and Safety	Evaluating nutritional status (Shakir strip has red and green regions indicating normal and at-risk conditions, both on the lower and the higher side), inequality in MUAC may be indication of trunk deformity, in particular, scoliosis (an improper exercise routine may, also, result in asymmetric muscle development)
Mathematics	Measurement of circumference, midpoint of distance between acromial and radial landmarks, significant difference between right and left arm as threshold of trunk-deformity risk, calibration — conversion of MUAC taken on clothing to that taken on body (Kamal, 1986; Kamal *et al.*, 2011*c*)
Physics	Measurement techniques, reproducibility of measurers, exertion of optimal pressure on arm, use of a mirror or camera/monitor to visualize opposite side of hand in order to make sure tailor's tape is horizontal
Quranic Studies	Measurement of right MUAC should precede left MUAC. According to the Holy Quran, men, who receive their deed-record in their right hands are successful and those, who receive the same in their left hands are doomed (verses 19-37, chapter 69, *Suratul-Haaqa*)

Fig. 8. Pedagogical and andragogical opportunities offered by the activity of measurement of MUAC

and teaching opportunities to introduce new concepts and experiences (Fig 6 and Fig. 7). An extension of imagination may result in similar listings for the measurement of mid-upper-arm circumference (Fig. 8).

5.1 Pedagogical and Andragogical Opportunities Offered by Height Measurement

These activities could be used to generate, illustrate and link concepts in various disciplines (Kamal, 2008). A situation, in which engineering tape is mounted in a tilted position by mistake, could be used to teach the following concepts (Kamal, 2011*b*)**:** (*a*) Computation of hypotenuse from perpendicular (trigonometry); (*b*) A line parallel to base intersects the sides of triangle such that the line segments are proportional (geometry). . The pedagogical and andragogical opportunities, generated from this activity are summarized in Fig. 6.

5.2 Pedagogical and Andragogical Opportunities Offered by Mass (Weight) Measurement

This simple activity can be a source of learning for students, if the measurer involves them in the process. The pedagogical and andragogical opportunities, generated from this activity are summarized in Fig. 7.

5.3 Pedagogical and Andragogical Opportunities Offered by MUAC Measurement

MUAC can serve as the first indictor of malnutrition. Fig. 8 shows pedagogical and andragogical opportunities, associated with this activity (Kamal *et al.*, 2011*b*).

6 ENDNOTES

[1]The claim of manufacturers of airport body-scanning systems (Kamal, 2010*b*) that the machine-generated data are destroyed in real time and not stored (whereas there is an additional claim that data can be stored during test runs) seems not to be consistent with current scientific practices. Airport-body-scanning machines are generating data in terms of images, which can not be destroyed as these data would be needed for research, debugging and post-disaster-security-lapse analyses (equivalent to black box of an aircraft).

[2]*Dupatta* is a garment worn on shoulders (on top of *kameez* — explained in Endnote 4), sometimes covering head, generally, in the Indian subcontinent, the Middle East and the Far East.

[3]*V* is a strip of cloth worn on shoulders (on top of *kameez*), generally, in the Indian subcontinent, the Middle East and the Far East.

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

[5]*Trainers* is an informal name for training shoes — running shoes for sport training.

[6]*Sneakers* are canvas shoes with rubber soles worn for sport or in informal setting — roughly equivalent to *plimsolls* in British English.

[7]*Pants* are meant here to be equivalent to trousers, as understood in the North America. In England, pants are, sometimes, meant to be used for underpants.

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

[9]*Abaya* or *burqa* is an outer garment worn by females, mainly, in Muslim culture.

[10]Box is provided for safekeeping of personal items — bow, cell phone, hair clips, pony, jewelry (bangles, bracelet, brooch, chain, ear ring, finger ring, locket), hairpins, tie, wallet, watch, *etc.*

[11]Measurer can stand on this chair for recording height of taller individuals.

[12]Picture available at https://www.ngds-ku.org/photos1/Fig_29.htm

[13]Picture available at https://www.ngds-ku.org/photos1/Fig_34.htm

[14]*Least count* is the least possible measurement, which could be obtained from a given instrument. For example, the least count of most wristwatches, these days, is 5 *seconds*.

[15]*Calibration* of a scientific instrument means someone is converting the output given in terms of variable *A* (which is not of interest) to variable *B* (which is required). This conversion would be easier if there is a linear relationship between the variables *A* and *B*. Examples are calibration of a thermometer (height of the mercury column, in *centimeters*, is converted to read in *centigrades*) or ammeter (needle deflection, in *degrees*, is converted to display current in *microampéres*).

[16]If the Vernier scale or the enhanced-Vernier scale mounted setsquares are not available; height should be taken with regular setsquares, which should provide measurements to least count of 0.1 *cm*.

[17]If the Vernier scale or the enhanced-Vernier scale mounted setsquares are not available; mass should be recorded with the regular beam scale, which should provide measurements to least count of 0.1 *kg*.

[18]Since $\mu_a = \mu + a,\ \mu_b = \mu + b,\ \mu_{a+b} = \mu + (a+b)$, where a is mass of the first set of clothing and b is mass of the second set of clothing. Now, $\mu_a + \mu_b - \mu_{a+b} = (\mu + a) + (\mu + b) - \mu - (a+b) = \mu$, which completes the proof.

[19] Do not take its value as $\frac{22}{7}$.

[20]*Prone* means palms of hands resting on thighs; *supine* means palms of hands (hand parallel to floor) facing eyes.

[21]A mirror on the wall behind or input from video camera to TV is needed to eliminate this source of error.

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ADDITIONAL RESOURCES (added after e-publication of this document)

a) On August 18, 2022**:**

Step-by-Step Protocols

Kamal, S. A., M. J. Ansari, M. Sarwar, S. A. Ansari, A. A. Naz and N. Jamil (2021). Percentiles of height-and-mass scaled for the Pakistani population**:** application to determine build of a gymnast. *Uluslararası Bozok Sport Bilimleri Dergisi* (*Bozok International Journal of Sport Sciences*), **2 (1):** 33-57, full text**:** https**:**//www.ngds-ku.org/Papers/J60.pdf

Additional File 1 — Techniques of Anthropometric Measurements (step-by-step protocols of measurement of height, mass and MUAC illustrated through labeled photographs)**:** https**:**//www.ngds-ku.org/Papers/J60/Additional_File_1.pdf

Video Series

Kamal, S. A. (2017, October 14). A series of 5 videos on 'Anthropometry of Children'

First Video — Introduction to Anthropometry of Children**:** https**:**//youtu.be/sXGGaM73S3E

Second Video — Preliminaries**:** https**:**//youtu.be/GxnEowK0AcE

Third Video — Measurement of Height of Children**:** https**:**//youtu.be/l1xs-xkhiBk
Fourth Video — Measurement of Mass of Children**:** https**:**//youtu.be/q916pgYCiC8
Fifth Video — Measurement of MUAC of Children**:** https**:**//youtu.be/O6pr7wfgA_0

b) On April 23, 2024**:**
Latest **'Informed Consent Form'** Used for anthropometric studies at the HND Program, the Bacha Khan University, Charsaada, KP, Pakistan (inserted on the following page). In order to ensure complete transparency and compliance, pictures of a boy and a girl are inserted, who are measured and weighed, dressed only in short underpants, all clothing above the waist removed (Fig. NGDS-1*a*-*d*).

*Web address of this document***:** https**:**//www.ngds-ku.org/ngds_folder/M02.pdf

The Bacha Khan University

Human Nutrition and Dietetics Program
and
THE NGDS PILOT PROJECT
PO Box 8423, University of Karachi, Karachi 75270

Dear Parent,

BKUC-NGDS-2024-

Kindly, quote this reference in future correspondence

Meritorious Professor Dr. Syed Arif Kamal, Ex-Dean, Faculty of Science, University of Karachi, undertook the NGDS Pilot Project to establish **"National Growth and Developmental Standards for the Pakistani Children"** [*The NGDS Pilot Project URL*: https://ngds-ku.org • *e-mail*: profdrakamal@gmail.com • *paper mail*: The NGDS Pilot Project, PO Box 8423, University of Karachi, Karachi 75270] under the directives of GOVERNOR SINDH/CHANCELLOR, UNIVERSITY OF KARACHI — a goodwill and a public-service endeavor conducted for the care and the development of young persons to prepare them mentally, physically and emotionally for rewarding careers in the civil and the military services. This project is being conducted success-fully since 1998 — over 1500 students measured and methods developed to determine detailed growth-and-obesity roadmaps. Trainings were imparted to research groups in Pakistan and abroad. In this connection, periodic measurements of height, mass, chest, waist and mid-upper-arm circumferences of your child shall be obtained as part of anthropometric study of HND Program of the Bacha Khan University, collaborating with the NGDS Pilot Project since 2023. You will receive Growth-and-Obesity Profile 4.5 of your son or daughter, which'll give CDC percentile-of-height/mass, pseudo-gain of height/mass (if present), estimated-adult height/mass (to find out at a very young age if your child is qualifying for induction in the Armed Forces of Pakistan) and estimated-adult-obesity profile (you'll have a chance to discuss all of these with the Project Director).

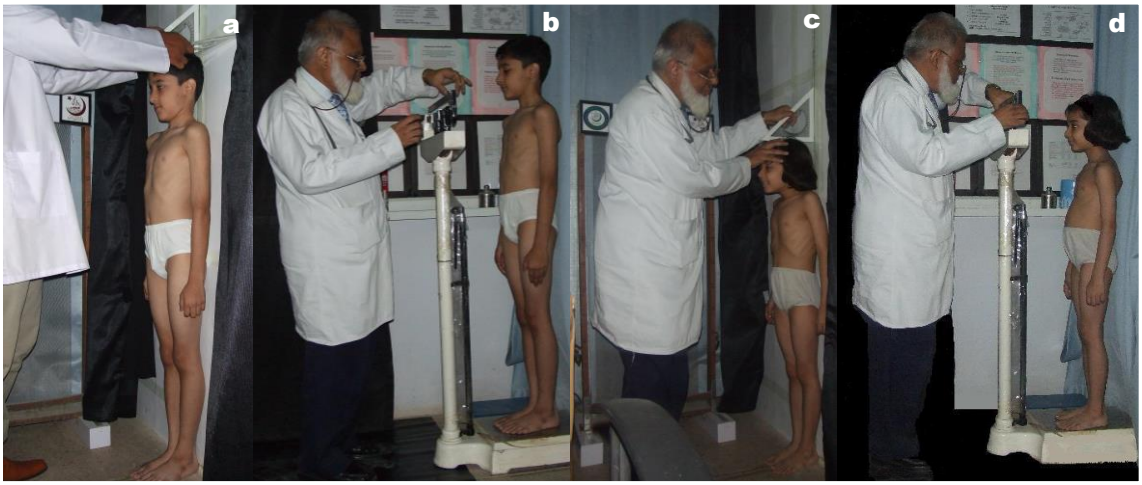

Fig. NGDS-1. Measurement of (*a*) Boy's height; (*b*) boy's mass; (*c*) girl's height; (*d*) girl's mass

The data obtained may be reported in research papers in collective form. The NGDS Pilot Project Website https://ngds-ku.org has photographs of procedures and reading material. As per international standards (as well as those of the Armed Forces of Pakistan), your child shall be measured wearing only short underpants, all clothing above the waist removed (Fig. NGDS-1*a*-*d*), so that accurate and precise measurements are obtained.

Kindly, fill in the following slip and return to Nutrition Laboratory before the measurement session.

Version 2.01 (2024-02-29)

Incharge, Nutrition Laboratory
and Project Director, the NGDS Pilot Project

THE BACHA KHAN UNIVERSITY **HND Program** **The NGDS Pilot Project**

Note: All names must be written in **BLOCK LETTERS.**
(Please do not write anything in the box above)

BKUC-NGDS-2024-

Version 2.01 (2024-04-29)

Kindly, don't forget **YEAR** when entering dates of birth

STUDENT'S NAME _____ Signatures _____
Class _____ Section _____ Boy/Girl _____ Date of Birth (Day-Month-**YEAR**) _____
FATHER'S NAME _____ Date of Birth _____ Signatures _____
MOTHER'S NAME _____ Date of Birth _____ Signatures _____
Address _____
Telephone Number _____ Best Time to Call _____ e-mail _____

HND Program, the Bacha Khan University, Palosa, Charsadda 24420, Khyber Pakhtunkhwa
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The NGDS Pilot Project, PO Box 8423, University of Karachi, Karachi 75270, Sindh
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Web address of this document: https://www.ngds-ku.org/Trainings/Forms/HND_Form_2024.pdf