A VERNIER-SCALE-BASED TAILOR'S TAPE WITH LEAST COUNT REDUCED TO 0.005 CENTIMETERS FOR MEASUREMENT OF MUAC, CHEST AND WAIST CIRCUMFERENCES OF SCHOOL-GOING CHILDREN[ρ]

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ABSTRACT

A prototype of tailor's tape, least count reduced to 0.005 *cm*, is presented. This is accomplished by making a sliding-Vernier scale, with 20 graduations matched to 19 graduations on the main scale of tailor's tape. Vernier-scale-based tailor's tape is used for measurements of chest circumferences, waist circumferences (indicator of fat content around abdomen) and MUAC (mid-upper-arm circumferences), the last one significant in determining nutritional status. The tape could, also, be used for obtaining hip circumferences (significant in determining over-fat conditions), thigh circumferences and shin circumferences. Engineering tape, made of metallic strip, cannot be used for these measurements, as it could inflict cuts on the skin. Accuracy and precision of this enhanced-Vernier scale is being investigated for measurements of chest circumferences, waist circumferences and mid-upper-arm circumferences. For determining accuracy and precision for measurements performed on a cylinder, diameter of this cylinder is measured to least count of 0.005 *cm* using Vernier calipers. This diameter is multiplied with π, having a value 3.14159….. ($^{22}/_{7}$ should not be used as value of π), to determine circumference, used in accuracy and precision formulae along with 10 measurements of circumference of cylinder. The accuracy and the precision for cylinder measurements come out to be 99.982% and 98.561%, respectively. Combined with setsquares for height measurement (least count 0.005 *cm*) and mass measurement (least count 0.005 *kg*), this Vernier-scale-based tailor's tape completes the triad of enhanced-measurement tools.

Keywords: Accuracy • chest circumference • mid-upper-arm circumference • precision • waist circumference

LIST OF ABBREVIATIONS

JCI: Joint **C**ommission **I**nternational • **MUAC: M**id-**U**pper-**A**rm **C**ircumference • **NGDS: N**ational **G**rowth and **D**evelopment **S**tandards for the Pakistani Children; a pilot project implemented since 1998 • **NIH:** The United States **N**ational **I**nstitutes of **H**ealth • **WHO: W**orld **H**ealth **O**rganization
Units: *cm* — centimeter(s) • *kg* — kilogram(s)

INTRODUCTION

Anthropometry is derived from *anthropology*, which gives understanding of variation of human-body physiques. The word anthropometry is understood as measurement of man. It deals with relative measurements of body dimensions, such as height, mass (weight), skinfold thickness, circumferences of waist, chest and mid-upper arm as well as their correlates over time. The most primitive measurements of the humans were performed in the ancient

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[ρ]The superscripts [*a-l*] refer to endnotes; keywords, list of abbreviations and units are arranged, alphabetically

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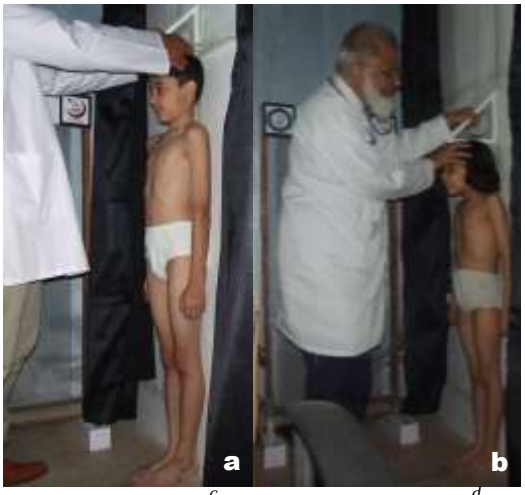

Fig. 1*a*, *b*. Measurement of height of (*a*) a 10-*year*-old[c] boy and (*b*) a 7-*year*-old[d] girl — (*a*) first appeared as Fig. 1*a* in Kamal and Jamil (2012) and (*b*) as Fig. 3*a* in Kamal and Jamil (2014); both pictures printed in the same journal

Greek and Roman civilizations. Hence, anthropometric data[a] of certain populations exist in the literature since early 1700s. However, organized anthropometric measurements on a larger scale are, regularly, being carried out in modern military setups.

Anthropometric measurements play a significant role in biomechanical and motor-performance research. They are utilized in the study of human sizes, shapes, proportions and compositions to understand human growth, development and maturation as well as nutritional status. An asymmetric growth might be an indicator of an underlying problem. Anthropometric studies are used in the fields of education, medicine, garment industry and government planning. For the growing school-going child, the importance of anthropometric measurements, taken at regular intervals to monitor growth and nutritional status, cannot be overemphasized. Many of the anthropometric measurements used are, grossly, inaccurate. The main hindrance in the general acceptance are a lack of universally-accepted selections of measurements, the use of crude equipment and the complicated nature of many of the suggested examinations with and without clothing.

HEIGHT AND MASS (WEIGHT) MEASUREMENTS (ENHANCED LEAST COUNTS)

Measurement of standing height and mass (weight) are those key anthropometric techniques, which are easy-to-interpret, inexpensive, nondestructive, noninvasive and simple-to-obtain. The strong points are that height as well as mass are consistent and not subject to many errors. However, internationally-agreed protocols should be employed and step-by-step procedures documented combined with appropriate training for anthropometrists so that they are able to generate reproducible results. To cater to these needs, a manual for obtaining anthropometric measurements has been prepared by the first author (Kamal, 2016) as well as step-by-step procedures illustrated with labelled photographs documented elsewhere (Kamal *et al.*, 2021, Additional File 1).

Failure to pick-up height in childhood may be the first warning sign that body systems are malfunctioning (Kamal, 2022). Enhanced-Vernier scale, capable of measuring height to least count[e] of 0.005 *cm*, was made by affixing strip on the setsquare edge so that 20 graduations on the Vernier scale measure up to 19 graduations on the main scale (Kamal *et al.*, 2016). Height-measurement instrument was calibrated using standard 100-*cm* ruler at the start of each daily session along with recording of zero errors[f]. For obtaining stature (measurement of height), the child, stripped to short underpants, all clothing above the waist removed, barefooted and bareheaded, is told to stand in contact with the mounted engineering tape, vertical alignment ascertained through plumb line. The child is instructed to align hands with body, palms on thighs and heels held together. Height is obtained with the child in attention position, fully inhaling to obtain the maximum chest expansion with abdomen in. A pencil is brought at the eye level to make sure that chin of the youngster remains parallel to floor (Kamal, 2016). Height should be measured before noon as the child is taller during the morning hours (Kamal, 2022). Figure 1 depicts measurements of heights of a boy and a girl.

Failure to put-on mass or losing mass rapidly may be indicator of a deeper underlying problem, mandating a head-to-toe stripped examination. Enhanced-beam scale, which can record mass to least count of 0.005 *kg*, was made by pasting strip on the setsquare edge so that 20 graduations on the Vernier scale measure up to 19 graduations

Fig. 2*a*, *b*. Recording of mass of (*a*) the boy and (*b*) the girl shown in Fig. 1 — (*a*) first appeared as Fig. 1*b* in Kamal and Jamil (2012) and (*b*) as Fig. 3*b* in Kamal and Jamil (2014); both pictures printed in the same journal

on the main scale (Kamal *et al.*, 2016). This scale was calibrated using standard 2-*kg* mass at the start of each daily session along with recording of zero errors. For obtaining mass (weight), the youngster, underdressed to briefs or panties, everything above the waist taken off, barefooted and bareheaded, with the youngster in stand-at-ease position, inhaling fully to get maximum chest expansion with tummy in. A pencil is brought at the eye level to be sure that chin of the child remains parallel to floor. Both height and mass should be obtained in the same session. Figure 2 shows recording of masses of a boy and a girl.

These enhanced-measuring instruments have been used, routinely, since their introduction in 2016 to obtain heights and masses of children at regular intervals (twice-a-*year*) to generate their Growth-and-Obesity Roadmaps (Kamal *et al.*, 2016). One must realize that a single measurement of height and weight of children is not of much value.

CONSTRUCTION OF VERNIER-SCALE-BASED TAILOR'S TAPE

We describe below the construction of Vernier-scale-based tailor's tape, which has a least count of 0.005 *cm*. This should complete the triad of enhanced-measurement tools.

An ordinary tailor's tape was taken and a sleeve was made, which was put on this tape. A Vernier scale was constructed by matching 20 divisions on this scale with 19 divisions on the main scale. This scale was glued to the open slit of the sleeve. The sleeve was, then, pasted to the main scale and a reference line was drawn at 5-*cm* mark. One must realize that because of this sleeve setup, measurement of circumferences could not be obtained using the starting of tape, as the sleeve opening was not available there (Figure 3). The measurement was, therefore, obtained at the reference line and 5 *cm* (interpreted as zero error) was subtracted from the measured value, to obtain true circumference (Figure 4).

Vernier-scale-based tailor's tape is used for measurements of chest circumferences, waist circumferences (indicator of fat content around abdomen) and MUAC, the last one significant in determining nutritional status. The tape could, also, be used for obtaining hip circumferences (significant in determining over-fat conditions), thigh circumferences and shin circumferences. Engineering tape, made of metallic strip, cannot be used for these measurements, as it could inflict cuts on the skin.

Fig. 3. Vernier-scale-based tailor's tape (least count 0.005 *cm*)

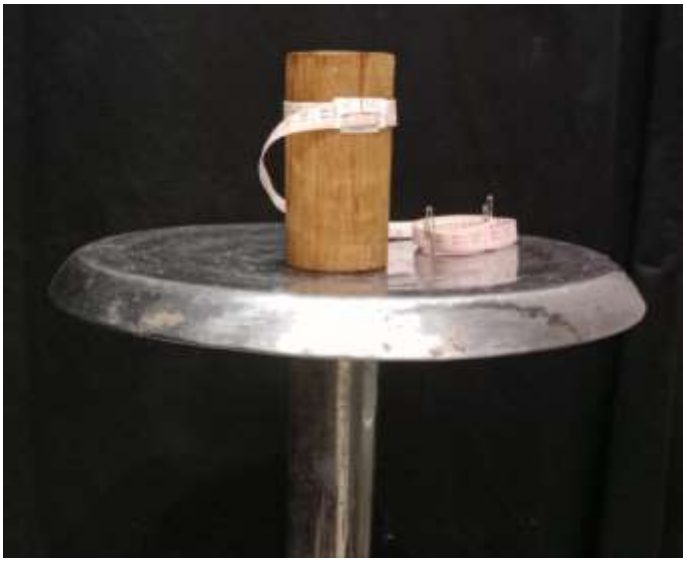

Fig. 4. Circumference of a cylinder obtained using tailor's tape (least count 0.005 *cm*)

***MUAC* (*Mid-Upper-Arm Circumference*)**

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. MUAC measurement is prone to greater variation among different readings because pressure applied may vary. The authors are in the process of developing a setup to ensure uniform measurement. Stankute *et al.* (2024) studied associations between neck circumference, MUAC, wrist circumference and high blood pressure among Lithuanian children and adolescents in a cross-sectional study. Bari *et al.* (2020) investigated patterns of maternal-nutritional status based on MUAC. In the appendix, we have included detailed protocols of measurement of MUAC.

Chest Circumference

Chest circumference is understood as the measurement around the chest area of an individual. In infants and young children, it is, relatively, smaller compared to the waist circumference, as the abdomen is protruding with weak abdominal muscles. For measurement of chest circumference, we ask the examinee to raise hands above the head in such a way that palms are touching with each other. If a plumb line is passed between the palms and is allowed to land freely it should, ideally, pass through naval (in children having trunk deformities this may not be accomplished). Tailor's tape is passed under the arms, the incumbent is asked to bring hands down and hold them close to body, palms touching thighs. Chest measurement is then measured with full inhaling (chest expanded) and exhaling (chest unexpanded). To make sure that the tape is at the same level on the back, a mirror/a camera connected to a TV monitor, is placed behind the back. Expanded and unexpanded chest circumferences are a measure of lung capacity of an individual, in particular, those participating in athletics. They are employed for induction in the military and the paramilitary organizations of a country as well as civilian-law-enforcement agencies. Fornasin *et al.* (2023) published a study of the military call-up registers from 1881 to 1909 in the context of chest circumference as well as structural and short-term changes. Mohan *et al.* (2012) investigated intra-rater reliability of chest expansion using cloth-tape-measure technique.

Waist Circumference

Waist circumference, in combination of hip circumference, is a measure of over-fat conditions in a person, which can identify risk of obesity. It is, widely, advocated as a simple anthropometric indicator of metabolic- and cardiovascular-disease risk, prediction of diabetes, congenital-heart disease and mortality rate. Despite the wide-spread use of waist-circumference measurements, there do not exist uniformly-accepted-measurement protocols. However, the most common ones are performed at these 4 sites, viz. (*i*) the umbilicus (the naval or the belly button), (*ii*) the minimal waist, (*iii*) midpoint of the lowest rib and the iliac crest and (*iv*) at the superior border of the iliac crest. Guidelines of NIH specify that waist circumference be measured directly above the superior border of the iliac crest. WHO and Health Canada recommend measurement at the midpoint between the superior border of the iliac crest and the lowest rib. Measurements performed at the umbilicus as well as at the minimal waist are, also, commonly used in the clinical and the research settings. Our group measures waist at the level of the umbilicus (the

naval), using a flexible, tension-sensitive and non-stretching tape. The child is asked to stand in attention position (palms touching on thighs), relax and exhale slowly. Measurement is taken after making sure that the tape is snug, without squeezing the skin (Jabeen *et al.*, 2010). Lockie *et al.* (2020) explored relationship of law-enforcement recruits to performance in physical-fitness tests in the context of waist circumference and waist-to-hip ratio. Ness-Abramof and Apovin (2008) recommend that waist circumference is a simple tool that should widely be implemented in clinical practice.

ACCURACY AND PRECISION

When one handles raw data, *similarities* appear in mean (measure of central tendency) or, more exactly, arithmetic mean

$$\overline{O} = \frac{1}{N}\sum_{i=1}^{N} O_i \tag{1}$$

and *differences* in deviation (measure of dispersion). An appropriate measure of dispersion to use is *standard deviation*, σ, when the data are normally distributed (large sample size, equal to or more than 100).

$$\sigma = \sqrt{\sum_{i=1}^{N} \frac{(O_i - \overline{O})^2}{N-1}} \tag{2a}$$

If that is not the case (sample size less than 100), one should employ *mean deviation*, *D*.

$$D = \sum_{i=1}^{N} \frac{\left|O_i - \overline{O}\right|}{N-1} \tag{2b}$$

Many times, accuracy (*A*) and precision (*P*) are confused. However, they represent completely different concepts.

Accuracy (*A*) is concerned with how far away, on the average; the observations are from the actual value. Mathematically, accuracy may be computed using the following formulae. Equation (3*a*) is applied, when the data are normally distributed (sample size equal to or more than 100), whereas equation (3*b*) is used, when the data are not normally distributed (Kamal, 2009).

$$A = 100\left[1 - \frac{\sigma_{\mathrm{R}}}{\sigma_{\mathrm{R}} + \overline{|O|}}\right]\% \tag{3a}$$

$$A = 100\left[1 - \frac{D_{\mathrm{R}}}{D_{\mathrm{R}} + \overline{|O|}}\right]\% \tag{3b}$$

σ_{R} is obtained upon replacing *arithmetic mean* by the *reference value*, *R*, in the expression of standard deviation, σ, equation (2*a*). The same holds for D_{R}.

Precision (*P*) is concerned with how far away, on the average; the observations are from the mean value. Equation (4*a*) is applied, when the data are normally distributed, whereas equation (4*b*) is used, when the data are not normally distributed (Kamal, 2009).

$$P = 100\left[1 - \frac{\sigma}{\sigma + \overline{|O|}}\right]\% \tag{4a}$$

$$P = 100\left[1 - \frac{D}{D + \overline{|O|}}\right]\% \tag{4b}$$

***Accuracy and Precision of a Cylinder* (*Reference Object*)**

To determine accuracy and precision, diameter of a cylinder was measured 5 times to least count of 0.005 *cm* using Vernier calipers[g] — zero error = 0 (Figure 5)**:**

5.495 *cm* • 5.490 *cm* • 5.495 *cm* • 5.490 *cm* • 5.495 *cm*

Arithmetic mean of this diameter, 5.493 *cm*, was multiplied with π, having a value 3.14159….. ($^{22}/_{7}$ should not be used as value of π), to compute circumference as 17.2568 *cm*. This value was used in formula of accuracy (equation 3*b*) along with 10 measurements of circumference of cylinder in (Table 1). Equation 4*b* was employed to determine precision. Data are not normally distributed, which could be checked from the fact that mean is different

Fig. 5. Measuring diameter of a cylinder in First-Year Laboratory, Department of Physics, University of Karachi

from median/mode.

The obtained values of accuracy and precision are given in the results section. In the appendix, we have demonstrated all the steps involved in the computation of accuracy (using equation 3*b*) and precision (using equation 4*b*) for 5 measurements of MUAC.

RESULTS

The accuracy of circumference measurements comes out to 99.98%, whereas the precision is computed as 98.56%[h].

CONCLUSION

For a child-growth model to be able to be utilized in clinical-decision making, it becomes necessary to devise a standard protocol for measurement — the equipment for anthropometric measurements should be easy-to-use and the procedures must be easy-to-implement as well as accurate, precise, reliable and reproducible. In order for the researchers throughout the globe to compare their findings, it is essential to establish standards. There is a need to write down SOPs (Standard-Operating Procedures), so that anthropometry of children becomes smooth, efficient and effective. In order to avoid variations introduced due to different types of clothing worn during summer and winter seasons as well as the child assuming an artificial posture, it is now, universally, accepted that measurements of children should be done with the youngster barefooted, bareheaded and totally stripped except for short underpants. Pre-collection planning, collection monitoring and post-collection analysis are keys to a successful anthropometric-data-collection campaign. Regular update of growth charts, based on standardized measurements, is an essential community-health activity of every civilized nation. Seventy-seven *years* have passed since the creation of Pakistan. However, we have not been able to establish our growth charts and tables for height and mass (weight) as well as other anthropometric measures. Pakistani pediatricians and community-health physicians need to take a proactive role in this direction. In this paper, the authors have constructed Vernier-scale-based tailor's tape capable of measuring to least counts of 0.005 *cm*. and investigated accuracy and precision of measurements of circumference of a cylinder. Combined with previously developed height- and mass-measurement tools, which are able to obtain measurements to least counts of 0.005 *cm* and 0.005 *kg*, respectively, it is hoped that the triad of these enhanced measurement tools should be a step forward in the Pakistani anthropometry scenario, which'll help generate reliable

Table 1. Descriptive statistics — qualitative and quantitative

Total number of circumference measurements**:**	10
Arithmetic mean**:**	17.2565 *cm*
Mean deviation**:**	0.252 *cm*
Median**:**	17.255 *cm*
Mode**:**	17.255 *cm*
Range**:**	(17.255-17.260) *cm*

future models of childhood obesity-and-malnutrition. A healthier and a stronger Pakistan must have been the dream of our founding fathers!

KEY POINTS

- *Anthropometry*, derived from *anthropology*, deals with relative measurements of body dimensions.
- Anthropometric measurements play a significant role in biomechanical and motor-performance research.
- A prototype of tailor's tape, least count reduced to 0.005 *cm*, is constructed by making a sliding-Vernier scale, with 20 graduations matched to 19 graduations on the main scale of tailor's tape.
- This tailor's tape is employed to measure MUAC, chest, waist and thigh circumferences.
- Accuracy and precision of such tailor's tape on a standard object (cylinder) are determined as 99.982% and 98.561%, respectively.

DECLARATION OF COMPETING INTERESTS

The authors state that there are no financial or non-financial competing interests in the research presented in this paper.

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APPENDIX: MID-UPPER-ARM-CIRCUMFERENCE (MUAC) MEAUREMENTS — PROTOCOLS AND COMPUTATION OF ACCRACY AND PRECISION

Below is a brief description of the method of measurement of MUAC. This method appeared for the first time in (Kamal, 2016) and step-by-step procedures explained with labelled photographs available elsewhere (Kamal *et al.*, 2021, Additional File 1). Even for a simple measurement, *e. g.*, height, weight, MUAC, informed consent must be obtained according to the applicable human-right protocols in the region. If the child is not in a life-threatening situation, it is better to follow *opt-in policy* (measurements are performed *only* on those children, whose parents send in 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). Figure 6 shows signing of consent form by a boy and a girl. Failure to adhere to this policy may result in denial of publication in a reputable journal (Kamal, 2016). The current consent form used by our group is available at https://www.ngds-ku.org/SGPP/Form.pdf

Dress code and behavior code during the measurement process should be recorded on the data form. Details are available in the manual (Kamal, 2016). It is imperative that anthropometric protocols should be standardized in order to obtain reproducible results (Kamal *et al.*, 2013). Attempt should be made to comply with JCI-infection-control protocols as well as KAK^{i}-patient-satisfaction protocols ((Kamal *et al.*, 2017).

Anthropometrists should have nails cut short and trimmed; hands washed and sanitized; bangles, hand-worn chains, rings and wristwatches removed before starting measurements (for safety reasons). Outside shoes, worn by children, parents or even staff, should be banned in lab area, where children walk barefoot. The surfaces, with which the child's body or underwear comes in contact, are checked for rough edges and sharp objects (child proofing). The above-mentioned

Fig. 6*a*, *b*. Signing of consent form by (*a*) the boy and (*b*) the girl shown in Fig. 1

Fig. 7. Positioning of feet of an 8-*year*-old[*j*] girl on wooden planks — first appeared as Fig. 5*a* in Kamal and Jamil (2014); picture printed in the same journal

areas should be cleaned and mopped, preferably using Dettol-mixed water (hygiene). The generic name of Dettol is chloroxylenol.

Both acoustic as well as visual privacy should be offered during the measurement sessions. Doors are closed and locked and second level of privacy is offered through a curtained-off area. Although, both parents are encouraged to come to the anthropometry session and share history and progress, same-gender parent is preferred to accompany the actual anthropometry in the curtained-off area to provide maximum comfort to the youngster. The measurement should be done in the morning between 9 a. m. to 12 noon, on both arms (so that the results are compared in the end), with the assistance of a social scientist or a teacher. The measurements of height, mass and MUAC should be obtained in a single session. It is imperative that the child should be completely undressed except for briefs or panties, barefooted (Figure 7) and bare-headed (Figure 8), all clothing above the waist removed. Full unclothing (taking off of all garments except underwear, stockings/socks/leggings, shoes, hair and other accessories) is necessary to visualize proper posture **(**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) as well as make sure that the child inhales completely during the measurement of MUAC. The measurer checks the level of floor using spirit level, where stool is to be placed. If the floor is not level (inclined), either the place is shifted or a wooden board is used, which is adjusted to horizontal level by keeping paper supports under its corners. The measurer asks the child to sit on stool and place both palms on thighs, arms aligned with the upper torso and breathe in to trap maximum air. If the child's feet do not touch the floor, wooden planks are placed on the floor so that the feet are resting on the plank and making an angle of 90^o with the shin (Figure 7). In case, legs are long, with the result that thigh and shin are making an obtuse (between 90^o and 180^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 the feet rest on the floor. The acromial and the radial landmarks are, then, located and labelled with a skin marker. This activity is dropped after the initial practice. The distance between the two landmarks is measured, carefully, with the help of tailor's tape (Figure 8). The number is divided by 2 to locate the midpoint between the two landmarks and a marker is employed to indicate the midpoint (abandoned after the initial practice). The circumference at the marked midpoint is measured with the help of tailor's tape, without stretching, in *cm* (Figure 9*a*). 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. Another way is to give a video input from video camera to TV. Since the child has been stripped for MUAC-measurement process, the measurer is able to observe that the child has fully inhaled (Figure 9*b*). The main source of hazard/injury is pressing too hard on the skin of hand and blocking circulation. The main sources of error may be summarized as not measuring exactly at the center, stretching the tailor's tape, measuring after exercise, measuring after IV (intravenous) infusion, swelling due to allergy/inflammation, elbows and knees not making an angle of 90^o, child holding on to something in hands, tailor's tape not parallel to the horizontal

Fig. 8. Measuring distance between acromial and radial landmarks on the arm of a 7-*year*-old[*k*] girl — first appeared as Fig. 5*b* in Kamal and Jamil (2014); picture printed in the same journal

Fig. 9*a*, *b*. Measuring MUAC of the same girl (*a*) sagittal view, noting down the actual reading and (*b*) frontal view[l] — (*a*) first appeared as Fig. 5*c* in Kamal and Jamil (2014); picture printed in the same journal

plane and, lastly, not inhaling completely.

This worked example is taken from an earlier presentation (Kamal, 2009, Additional File). A *medical student* (she just started her clerkship in pediatrics) and a *professional anthropometrist*, both took MUAC of a 7-*year*-old girl. The data of the right-arm measurement are given in Table 2. By computing accuracy and precision, one needs to identify *medical student/professional anthropometrist* (measurer M_1 or M_2) — reference value of MUAC is 16.5 *cm*. Mean deviation (D) is used instead of standard deviation (σ) as the data are not normally distributed — number of observations being only 5.

Accuracies (A) of measurers M_1 and M_2 are computed in Table 3*a* using equation (3*b*), precisions (P) in Table 3*b* using equation (4*b*).

Measurer M_1**:** $\overline{O} = \frac{1}{N}\sum_{i=1}^{N} O_i = \frac{83.3}{5} = 16.66\ cm \bullet \overline{|O|} = \frac{83.3}{5} = 16.66\ cm$

$$D = \sum_{i=1}^{N} \frac{|O_i - \overline{O}|}{N-1} = \frac{1.24}{4} = 0.31\ \ cm \bullet D_R = \sum_{i=1}^{N} \frac{|O_i - R|}{N-1} = \frac{1.4}{4} = 0.35\ \ cm$$

$$A = 100\left[1 - \frac{D_R}{D_R + \overline{|O|}}\right]\% = 97.942386832\% \bullet P = 100\left[1 - \frac{D}{D + \overline{|O|}}\right]\% = 98.173246907\ \%$$

Measurer M_2**:** $\overline{O} = \frac{1}{N}\sum_{i=1}^{N} O_i = \frac{82.5}{5} = 16.5\,cm \bullet \overline{|O|} = \frac{82.5}{5} = 16.5\,cm$

$$D = \sum_{i=1}^{N} \frac{|O_i - \overline{O}|}{N-1} = \frac{0.4}{4} = 0.1\ \ cm \bullet D_R = \sum_{i=1}^{N} \frac{|O_i - R|}{N-1} = \frac{0.4}{4} = 0.1\ \ cm$$

$$A = 100\left[1 - \frac{D_R}{D_R + \overline{|O|}}\right]\% = 99.397590362\ \%\bullet P = 100\left[1 - \frac{D}{D + \overline{|O|}}\right]\% = 99.397590362\ \%$$

A comparative statement is prepared (Table 4), which shows that measurer M_2 has, not only, *higher precision* (indicator of good work habits), 99.397590362% ≈ 99.4% (to proper significant figures) as compared to 98.173246907% ≈ 98.2%, for measurer M_1, but also, *higher accuracy* (indicator of accessibility to good instruments), 99.397590362% ≈ 99.4% as compared to 97.942386832% ≈ 97.9%, for measurer M_1.

According to these results, measurer M_2 seems to be *professional anthropometrist*, whereas measurer M_1 looks like *medical student*. In case, the *professional anthropometrist* forgot his glasses on the day of measurement, his precision should have been higher, but accuracy might have dropped. Figure 10 lists pedagogical and andragogical opportunities offered by the activity of measurement of MUAC.

ENDNOTES

[a]*Data* (should not be used in singular form) is plural of *datum* (meaning 'one piece of information'); hence 'are' is used instead of 'is'

Table 2. Measured MUAC values of a 7-*year*-old girl

MUAC (*cm*)	*1st*	*2nd*	*3rd*	*4th*	*5th*
Measurer M_1	16.4	16.3	16.7	16.8	17.1
Measurer M_2	16.5	16.6	16.4	16.6	16.4

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 the right and the left arm as threshold of trunk-deformity risk, calibration — conversion of MUAC taken on clothing to that taken on body
Physics	Measurement techniques, reproducibility of measurers, exertion of optimal pressure on arm, use of a mirror or a camera and a TV/a 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 measurement of 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 — English translation (slightly modified by the first author) are taken from https://myislam.org/surah-al-haqqah/**:** So as for he who is given his record in his right hand, he shall say, "Here, read my record! Indeed, I was certain that I would be meeting my account." So, he shall be in a pleasant life – in an elevated garden, its [fruit] to be picked hanging nearby. [They will be told], "Eat and drink in satisfaction for what you put forth in the days past." But as for he, who is given his record in his left hand, he shall say, "Oh, I wish I had not been given my record and had not known what my account is. I wish my death had been the decisive one. My wealth has not availed me. Gone from me is my authority." [*Allah Izz-o-Jal* shall say], "Seize him and shackle him. Then into Hellfire drive him. Then into a chain, whose length is seventy cubits, insert him." (*Al-Hāqqah*, 69**:** 19-32 — *Al-Quran*)

Fig. 10. Pedagogical and andragogical opportunities offered by the activity of measurement of MUAC

[b] *British***:** medallist (American spelling is used in this paper) — a person, who is awarded a medal

[c] *Date of Birth***:** December 22, 1998 • *Date of Measurement***:** November 1, 2009 • *Age***:** 10 *years* 10 *months* 09 *days*

[d] *Date of Birth***:** December 1, 2001 • *Date of Measurement***:** November 1, 2009 • *Age***:** 07 *years* 11 *months*

[e] *Least count* is the least possible measurement, which could be obtained from a given instrument

[f] *Zero error* is the reading on an instrument for zero measurement; the first author is indebted to his teacher, **Hussain Ahmed Bilgrami**, who taught him this definition in 1971 — concepts of the Vernier-scale-based tailor's tape and, earlier, the Vernier-scale-based setsquares for height measurement as well as the enhanced-beam scale for mass measurement (Kamal, 2010; Kamal *et al.*, 2016) were inspired by a laboratory session of his teacher, in which he asked the students to construct Vernier scales having different least counts; the lead author had the honor to organize *the Second Conference on Anthromathematics and Sport Mathematics* in his teacher's memory in 2014 and deliver *the H. A. Bilgrami memorial lecture* (Kamal *et al.*, 2014) — in other words, zero error is a systematic error that occurs, when an instrument does not read zero, for a quantity to be measured that is zero (zero error is always subtracted from the reading given by an instru-

Table 3*a*. Accuracy and precision computation of measurer M_1 (reference value, $R = 16.5\ cm$)

i	$O_i\ (cm)$	$\lvert O_i \rvert\ (cm)$	$(O_i - \overline{O})\ (cm)$	$\lvert O_i - \overline{O} \rvert\ (cm)$	$(O_i - R)\ (cm)$	$\lvert O_i - R \rvert\ (cm)$
1	16.4	16.4	–0.26	0.26	–0.1	0.1
2	16.3	16.3	–0.36	0.36	–0.2	0.2
3	16.7	16.7	0.04	0.04	0.2	0.2
4	16.8	16.8	0.14	0.14	0.3	0.3
5	17.1	17.1	0.44	0.44	0.6	0.6
∑	83.3	83.3		1.24		1.4

Table 3*b*. Accuracy and precision computation of measurer M_2 (reference value, $R = 16.5\ cm$)

i	$O_i\,(cm)$	$\lvert O_i\rvert\,(cm)$	$(O_i-\overline{O})\,(cm)$	$\lvert O_i-\overline{O}\rvert\,(cm)$	$(O_i-R)\,(cm)$	$\lvert O_i-R\rvert\,(cm)$
1	16.5	16.5	0.0	0.0	–0.1	0.1
2	16.6	16.6	0.1	0.1	–0.2	0.2
3	16.4	16.4	–0.1	0.1	0.2	0.2
4	16.6	16.6	0.1	0.1	0.3	0.3
5	16.4	16.4	–0.1	0.1	0.6	0.6
∑	82.5	82.5		0.4		0.4

ment); in the Vernier-scale-based setup described in this paper, an *artificial-zero* error is introduced (zero measurement of circumference reads 5 *cm* on Vernier scale) to make the measurement possible to least count of 0.005 *cm*

[g]*British*: callipers (American spelling is used in this paper) — invented by the French mathematician **Pierre Vernier**

[h]Rules of significant figures must be borne in mind, when quoting the final result (Kamal, 2008) — these rules are illustrated in Figure 11

[i]KAK stands for Kamal-Azeemi-Khan (Kamal *et al.*, 2017)

[j]*Date of Birth*: Apr. 25, 2003 • *Date of Measurement*: Jan. 28, 2012 • *Age*: 08 *years* 09 *months* 03 *days*

[k]*Date of Birth*: Oct. 27, 2001 • *Date of Measurement*: May 17, 2009 • *Age*: 07 *years* 06 *months* 20 *days*

[l]Note that the child is not putting hands on thighs in this picture as she is asked to pull hands slightly so that tape could be passed through her arm

Table 4. Accuracies and precisions of measurers M_1 and M_2

	Accuracy	*Precision*
Measurer M_1	97.9 %	98.2 %
Measurer M_2	99.4 %	99.4 %

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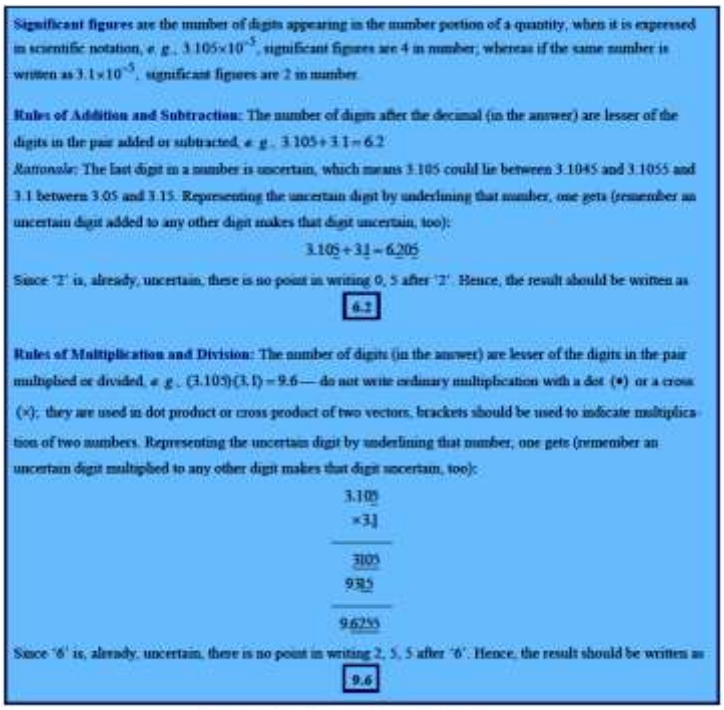

Fig. 11. Rules for handling the significant figures

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