Anthropometric measurements

I. Aim of the practical

Students are to perform a few anthropometric measurements relevant to medical practice; furthermore, to discover the most important derived indicators. Through the simple measurements of mass and length and the calculation of derived parameters, students will get acquainted with basic concepts of medical measurements (precision, reproducibility, repeated measurements), with sources of measurement errors and their elimination, and learn the main aspects of preparing a lab report.

II. Background

A. Anthropometry and measurement

Anthropometry (< Greek *άνθρωπος*, 'man', and *μέτρον*, 'measure', literally meaning 'measurement of humans'), refers to the measurement of the human individual for the purposes of understanding human physical variation. It evolved as a branch of anthropology, but today it is extensively used in medicine and ergonomics as well.

> Ergonomics is the science of designing the job, equipment and workplace to fit the worker. Proper ergonomic design is necessary to prevent repetitive strain injuries, which can develop over time and can lead to long-term disability. Ergonomics is employed to fulfil the two goals of health and productivity. It is relevant in the design of such things as safe furniture and easy-to-use interfaces to machines.
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> Anthropometry is applied in various fields of medicine (paediatrics, endocrinology, forensics, etc.). It has major importance in evaluating risk factors in metabolic syndromes (obesity, diabetes, etc.) and in the follow up of eating disorders.
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> With the continuous advancement of anthropometry, methods are now available to determine not only the dimensions of the human body, but the proportions of its main constituents.

In all phases of the medical practice, we perform measurements in order to quantify physiological parameters for comparison with relevant values of the healthy population, or former data of the same individual. Measurement is therefore a part of everyday practice in medicine.

During measurement the subject (the person studied) is placed in a well-defined environment with controlled temperature, lighting conditions and air quality. To perform the measurement, one uses a measurement device, follows a measurement protocol to determine a characteristic quantity X, given by a number $\{X\}$ and a unit $[X]$. The number is given up to the relevant significant digits determined by the measurement conditions.

> The three major elements of the measurement are the measured object, the protocol for measurement and the result.
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> The measurement device uses/follows the protocol to transform the quantities of the measured object to an output/value related to the scale that is integral to the device.
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> The characteristics and thus the precision of a measurement device may change as the device is being used. This warrants their regular supervision, which in many cases is also prescribed by legislation. Calibration comprises processes in which we determine which values X_p of the quantity to be measured should be assigned to values X_m shown by the device through a comparison to another, independent measurement device.

B. Measurement error

Detailed measurement error analysis goes beyond the frame and scope of the present course, so we restrict ourselves to discussing a few practical issues.

The most important issue is to state that all measurements carry some type of error, or inaccuracy. Note: an error is not a 'mistake'. Variability is an inherent part of things being measured and of the measurement process.

We define the error of a measurement as the magnitude of the difference between the real value *M* and the measured value *X*.

Possible sources of errors:

1) *Systematic error*, which always occurs (with the same value) when we use the instrument in the same way.

Systematic errors are predictable, and typically constant or proportional to the true value. If the cause of the systematic error can be identified, then it can usually be eliminated. Systematic errors are caused by imperfect calibration of measurement instruments or imperfect methods of observation, or interference of the environment with the measurement process, and always affect the results of an experiment in a predictable direction.

2) *Random error* which may vary from observation to observation. The random error is due to factors which we cannot (or do not) control. Random errors are errors in measurement that lead to measured values being inconsistent when repeated measures of a constant attribute or quantity are taken. The word random indicates that they are inherently unpredictable, and have null expected value, namely, they are scattered about the true value, and tend to have null arithmetic mean when a measurement is repeated several times with the same instrument. To reduce random error one has to take multiple measurements in the same conditions, and use statistical methods for evaluation.

The numerical value of a measurement has a meaning only if the accuracy (error) is shown. We have to define to what precision the value is correct, what its reliability is. Obviously the measurement mass resulting in 1±0.01 g (using analytic balance) or 1±1 g (on kitchen scales) with the different margins of error will mark the reliability of the data.

Sometimes the accuracy of the measurement device limits the accuracy of measurements, and we might get the same reading with repeated measurements (try to determine the height of a person with a chart that has one scale reading every centimetre). In this case we cannot say that the measurement has no error, but rather we set the error of measurement as the accuracy of the measuring device (in this case 1 cm).

Measurement error can be expressed as

– an absolute error, which is the maximum of the absolute difference of the measured values (X_i) from the actual value (R)

$$\Delta = X - R$$

Absolute error in itself does not characterise the accuracy of measurement. Distance measurements of 3 m ± 3 mm and 3 cm ± 3 mm have the same absolute error, but they obviously require different precision. Therefore measurement error is often expressed as

– a relative error:

$$\delta = \frac{X - R}{R} \cdot 100\%$$

which is the magnitude of error relative to the 'exact' value.

The formulae above assume that the real value *R* of the quantity is known. Most of the time, this is not the case: we have to describe the value of the quantity solely on the basis of our measurements. We measure the same quantity several times (the more measurements we take, the less the uncertainty), and use the tools of statistics to infer the value of the quantity. The best estimate of the real value is the *mean value* (average) of the measured values X_i:

$$\bar{X} = \frac{1}{N}\sum_{i=0}^{N-1} X_i,$$

where *N* is the number of measurements. The error of the measurement is derived from the *standard deviation,* which is a measure of the scattering of the data about the mean:

$$\sigma_{N-1} = \sqrt{\frac{1}{N-1}\sum_{i=0}^{N-1}(X_i - \bar{X})^2}\,.$$

To quantify the result of the measurement fully, we use the *confidence interval:* an interval which contains the real value of the quantity with a given probability. This probability is called the *confidence level.* Thus the measurement result is given as

$$\bar{X} - \Delta X < X < \bar{X} + \Delta X,$$

or in shorter form,

$$X = \bar{X} \pm \Delta X,$$

where ΔX denotes the error of the measurement. The error ΔX is calculated from the standard deviation and depends on the confidence level (the more certain we intend to be – the higher the confidence level –, the wider the interval which will contain the real value with the prescribed probability) and on the number of measurements. If we perform *N* measurements, the measurement error is specified as

$$X = \bar{X} \pm \frac{\lambda\sigma}{\sqrt{N}},$$

where λ is a parameter that depends on the confidence level and whose value is usually taken from the appropriate table. The standard deviation σ is either known (eg, when the statistical error is caused by the measurement device and the specifications contain its value), or we use the formula above to obtain its empirical value from the measurement values. The parameter λ is calculated on the basis of our assumptions on the distribution of the data. This calculation is addressed by statistics and we shall not discuss the details here.

Often not only do we use the directly measurable values for evaluation of a problem, but we also derive other quantities (eg, BMI) from measured data (height and mass). Propagation of error is the effect of variables' uncertainties (or errors) on the uncertainty of a function based on them. When the variables are the values of experimental measurements, they have uncertainties due to measurement limitations (eg, instrument precision) which propagate to the combination of variables in the function. Propagation of error is dealt with using calculus and we shall not go into details here.

III. Measurement tasks:

The group is divided the subgroups of ≈4 people. In every subgroup each student shall measure the

1. height
2. hip size (circumference)
3. waist size (circumference) (2–3 cm above the navel)
4. mass

of every other student in the subgroup.

IV. Calculation tasks:

A. Metabolic parameters

1. Body mass index

The body mass index (BMI), or Quetelet index, is a statistical measure of body weight based on a person's weight and height. Though it does not actually measure the **percentage of body fat**, it is used to estimate a healthy **body weight** based on a person's height. Due to its ease of measurement and calculation, it is the most widely used diagnostic tool to identify weight problems within a population, usually whether individuals are **underweight**, **overweight** or **obese**.

$$\mathrm{BMI} = \frac{\mathrm{mass\ [kg]}}{\mathrm{height}^2\ [\mathrm{m}^2]}$$

Calculate your own body mass index. How many digits are significant? What is the error of the derived value?

Category	BMI range – kg/m^2
Severely underweight	less than 16
Underweight	from 16 to 18.49
Normal	from 18.5 to 24.99
Overweight	from 25 to 29.99
Obese Class I	from 30 to 34.99
Obese Class II	from 35 to 39.99
Obese Class III	over 40

2. Waist circumference

According to the new IDF definition, for a person to be defined as having metabolic syndrome they must have:

sex	Moderate risk group	high risk group
male	> 94 cm waist circumference	> 102 cm waist circumference
female	> 80 cm waist circumference	> 88 cm waist circumference

Central obesity is defined as waist circumference > 94 cm for Europid men and > 80 cm for Europid women, with ethnicity specific values for other groups.

3. Waist-hip ratio

The waist-hip ratio is obtained by dividing the waist circumference (measured in cm) by the hip circumference (also measured in cm). Some studies show that the waist-hip ratio gives a better indication of the metabolic syndrome than the BMI or the waist circumference. A risk of central obesity is indicated at a waist-hip ratio > 0.90 (male); > 0.85 (female).

B. Calculation of body surface area

The metabolism of several pharmaceuticals shows strong correlation with the body surface area (BSA). Most chemotherapeutic drugs are administered in quantities related to BSA and so it is necessary to be able to determine BSA in medical practice.

1. Simplest assumptions

Assume your body to be a sphere! Using your body mass, determine the surface area! What would be the surface area of a cube of your mass and your density?

You might find the following formulae useful:

$$m = \rho \cdot V, \qquad A_{\text{sphere}} = 4 \cdot R^2 \cdot \pi, \qquad V_{\text{sphere}} = \frac{4}{3} R^3 \cdot \pi, \qquad A_{\text{cube}} = 6 \cdot a^2, \qquad V_{\text{cube}} = a^3$$

Use values of 1030 kg/m^3 (for females) and 1040 kg/m^3 (for males) as the density of the human body.

2. Empirical formulae

Various empirical formulae have been published to arrive at the BSA without direct measurement:

The Mosteller formula, published in 1987 and adopted for use by the Pharmacy and Therapeutics Committee of the Cross Cancer Institute, Edmonton, Alberta, Canada:

$$\text{BSA}\ [\text{m}^2] = \sqrt{\frac{\text{height [cm]} \cdot \text{mass [kg]}}{3600}}$$

One commonly used formula is the Dubois & Dubois formula:

$$\text{BSA}\ [\text{m}^2] = 0.007184 \cdot \text{height [cm]}^{0.725} \cdot \text{mass [kg]}^{0.425}$$

Other formulae include the Haycock formula:

$$\text{BSA}\ [\text{m}^2] = 0.024265 \cdot \text{height [cm]}^{0.3964} \cdot \text{mass [kg]}^{0.5378}$$

and the Gehan and George formula:

$$\text{BSA}\ [\text{m}^2] = 0.0235 \cdot \text{height [cm]}^{0.42246} \cdot \text{mass [kg]}^{0.51456}$$

Calculate your own BSA using the formulae above. Compare the obtained values. Determine the relative difference as compared to the value obtained by the Mosteller formula.