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Development of innovative training solutions in the field of functional evaluation aimed at updating of the curricula of health sciences schools

TEACH

MODULE BIOMECHANICS: FOUNDATIONS OF BIOMECHANICS APPLIED TO THE LOCOMOTOR SYSTEM

Didactic Unit E: TECHNIQUES FOR THE INSTRUMENTAL ANALYSIS OF PHYSIOLOGICAL SIGNS AND ANTHROPOMETRIC AND MORPHOMETRIC PARAMETERS?

E.3. How can I measure morphometric and anthropometric parameters?

Politechnika Śląska
IBV INSTITUTO DE BIOMECÁNICA DE VALENCIA
VNIVERSITAT DE VALÈNCIA
AMSE THE ASSOCIATION OF MEDICAL SCHOOLS IN EUROPE

Index

1. Objectives

- To learn what are the meaning of morphometric and anthropometric parameters measurement.
- To know main types of morphometric and anthropometric parameters and their measurement procedures.
- To be able to use measurement methods for chosen anthropometric parameters estimation both in classical, manual approach and modern approach, by means of advanced bio-sensors and electronic automated measurement systems.

2. What are anthropometric measurements?

Anthropometric measurements are a series of quantitative measurements of the muscle, bone, and adipose tissue used to assess the composition of the body. The core elements of anthropometry are height, weight, body mass index (BMI), body circumferences (waist, hip, and limbs), and skinfold thickness. These measurements are important because they represent diagnostic criteria for obesity, which significantly increases the risk for conditions such as cardiovascular disease, hypertension, diabetes mellitus, and many more.

There is further utility as a measure of nutritional status in children and pregnant women. Additionally, anthropometric measurements can be used as a baseline for physical fitness and to measure the progress of fitness.

Some common anthropometric measurements include:

- Height or length
- Weight
- Mid-upper arm circumference (MUAC)
- Demi-span or arm span
- Knee height
- Sitting height
- Skin fold thickness
- Head circumference

Height (or length) and weight are the most common anthropometric measures used to indicate protein-energy nutritional status in emergencies.

Anthropometric measurements are combined with each other or with other data to calculate anthropometric indices. The most common indices used in emergencies include those listed in the table below:

Index	Nutritional problem measured
Weight-for-height	*Acute malnutrition (wasting)*
Height-for-age	*Chronic malnutrition (stunting)*
Weight-for-age	*Any protein-energy malnutrition (underweight)*

If you want to measure the prevalence of acute protein-energy malnutrition, you should use weight-for-height. However, in practice, all three indices are usually available. Most emergency nutrition surveys measure sex, height, weight, and age. From these measurements, all three anthropometric indices can be easily calculated by a computer.

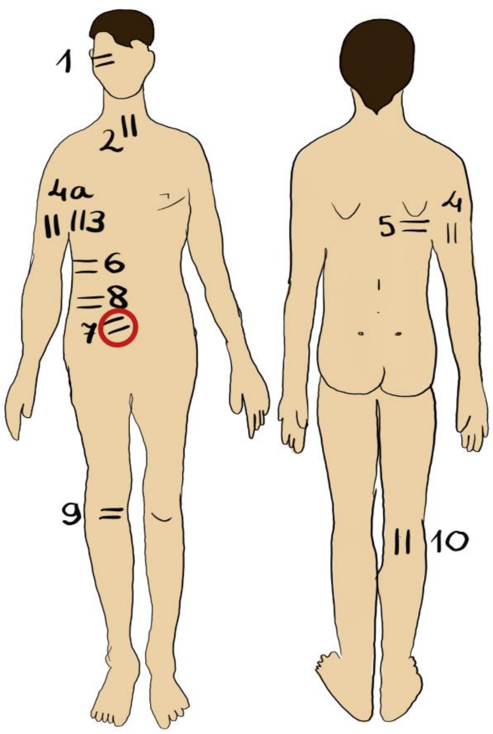
3. What are the methods anthropometric measurements?

Classical approach using manual measurement tools.

Equipment:

- Weight scale
- Calibration weights
- Box to sit on
- Stadiometer
- Knee caliper
- Skinfold calipers
- Tape measure
- Infantometer to measure recumbent length

Characteristic points for measurements. Geometrical indicators



Skinfold thickness measurement

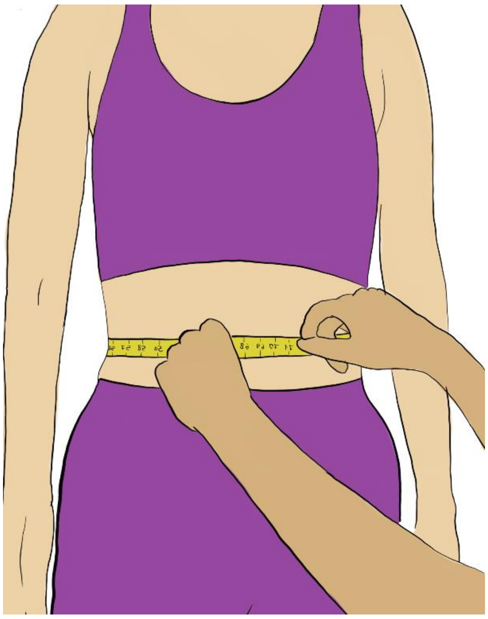
Grasp the skinfold firmly between your thumb and index finger of your left hand. The skinfold is lifted 1 cm and recorded with the callipers held in the right hand. Keep the fold elevated while the measurement is recorded. Take the skinfold measurement 4 seconds after the calliper pressure is released.

Precision skinfold thickness callipers are used to measure the double fold of skin and subcutaneous fat to the nearest millimeter. The usual sites of measurement are at the triceps (TSFT), the midpoint of the back of the upper arm; the biceps at the same level as the TSFT but to the front of the upper left arm; the subscapular (SSFT) just below and laterally to the left shoulder blade, and the suprailiac (SISFT) obliquely just above the left iliac crest. Skinfold thicknesses can also be measured at the midthigh, midcalf, and abdomen.

Skinfold thicknesses are difficult measurements to make with precision and accuracy without rigorous training. It is difficult to pick up a consistent fold of skin and subcutaneous fat; in the very obese, the skinfold may be bigger than the callipers can measure; the fold of skin and fat compresses with repeated measurements; and the careless use of the callipers causes pain, bruising, and skin damage to subjects. There is, therefore, likely to be considerable inter- and intraobserver error in the measurements.

Head circumference (HC) is a measurement of the head around its largest area, typically measured on infants and children until the age of five years as part of routine child care. It measures the distance from above the eyebrows and ears and around the back of the head.

The waist-hip ratio or waist-to-hip ratio (WHR) is the dimensionless ratio of the circumference of the waist to that of the hips. This is calculated as waist measurement divided by hip measurement (W/H). For example, a person with a 30″ (76 cm) waist and 38″ (97 cm) hips has a waist-hip ratio of about 0.78.

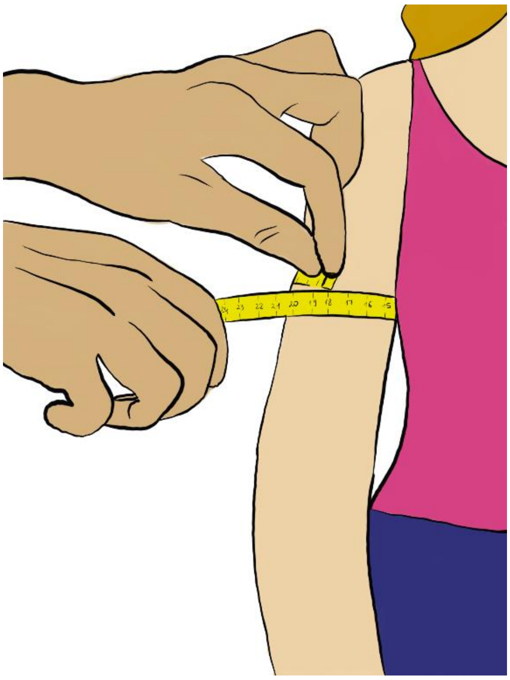


The WHR has been used as an indicator or measure of health, fertility, and the risk of developing serious health conditions. WHR correlates also with perceptions of physical attractiveness.

According to the World Health Organization's data gathering protocol the waist circumference should be measured at the midpoint between the lower margin of the last palpable ribs and the top of the iliac crest, using a stretch-resistant tape that provides a constant 100 g tension. Hip circumference should be measured around the widest portion of the buttocks, with the tape parallel to the floor. [3] Other organizations use slightly different standards. The United States National Institutes of Health and the National Health and Nutrition Examination Survey used results obtained by measuring at the top of the iliac crest. Waist measurements are usually obtained by laypersons by measuring around the waist at the navel, but research has shown that these measurements may underestimate the true waist circumference. [3]

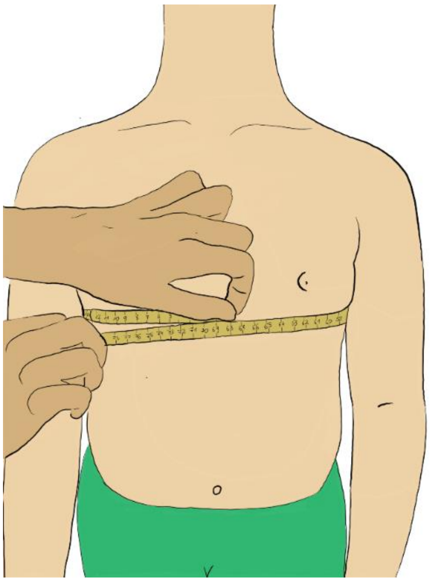
For both measurements, the individual should stand with feet close together, arms at the side and body weight evenly distributed, and should wear little clothing. The subject should be relaxed, and the measurements should be taken at the end of a normal respiration. Each measurement should be repeated twice; if the measurements are within 1 cm of one another, the average should be calculated. If the difference between the two measurements exceeds 1 cm, the two measurements should be repeated.

Mid arm circumference



The measuring point is halfway between the olecranon process of the ulna and the acromion process of the scapula. The mid-upper arm circumference is the circumference of the upper arm at that same midpoint, measured with a non-stretchable tape measure or 3D printable bands.

Chest circumference

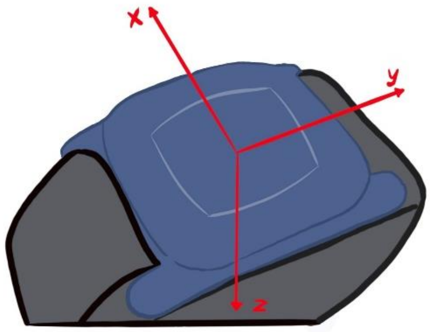


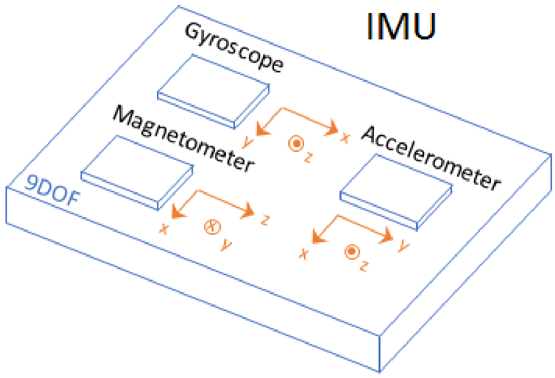
Chest circumference was measured at the level of the nipple, at the end of expiration, to the nearest 0.1 cm using a non-elastic, flexible, fibre glass measuring

Modern, innovative Inertial Measurement Units (IMU) to assess anthropometric signs by body part position and movements.

An Inertial Measurement Unit, also known as IMU, is an electronic device that measures and reports acceleration, orientation, angular rates, and other gravitational forces. It is composed of 3 accelerometers, 3 gyroscopes, and depending on the heading requirement – 3 magnetometers. That is to say, one per axis for each of the three vehicle axes: roll, pitch, and yaw.

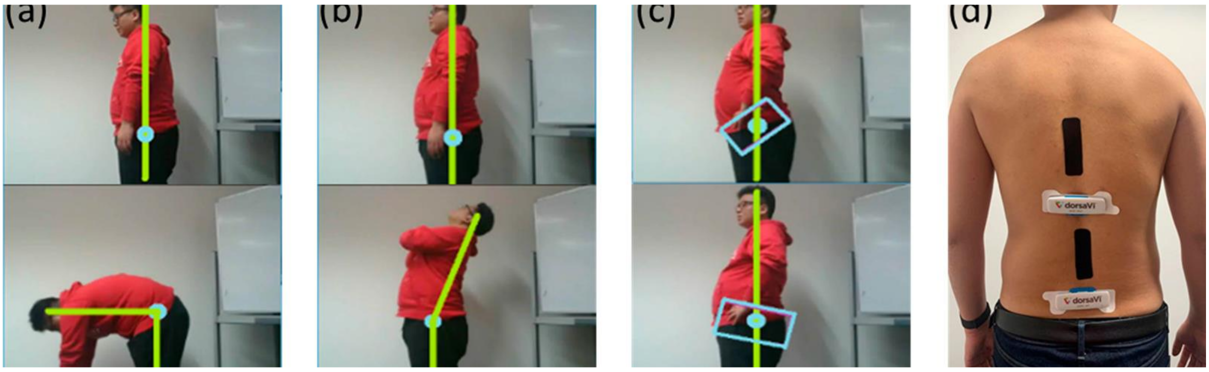
There are different types of IMU sensors: the one based on FOG (Fiber Optic Gyroscope), the RLG IMUs (Ring Laser Gyroscope), and lastly, IMU based on MEMS technology (Micro Electro-Mechanical Systems). This technology allows lower costs and low power requirements while ensuring performance. MEMS-based systems therefore combine high performance and ultra-low power in a smaller unit.





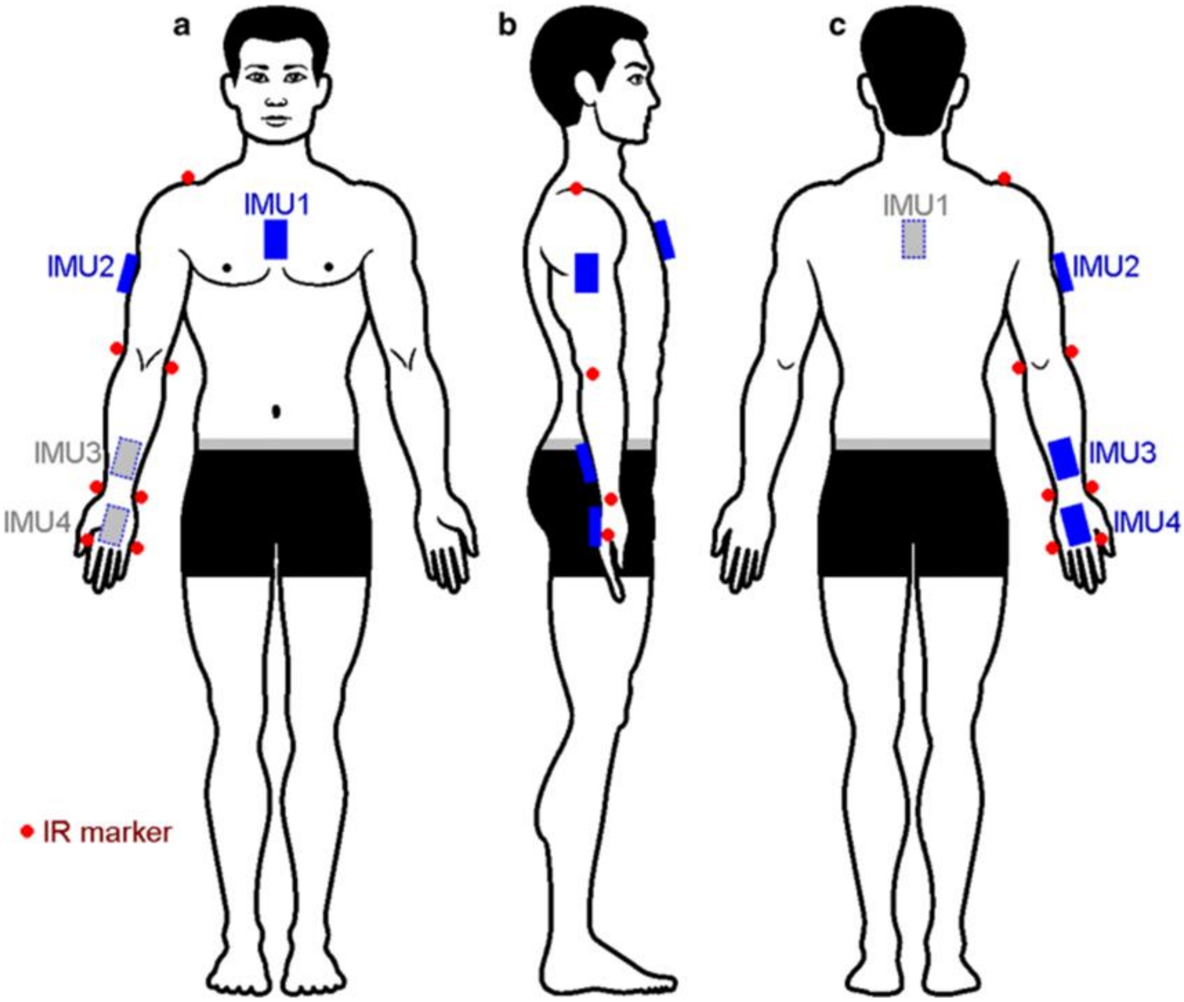
One common characteristic of systems for anatomical angles detection is to compute the angle by sensing coordinates of different points on a human body in a three-dimensional space. This data can also be used to calculate the speed, acceleration, and direction of the angle.

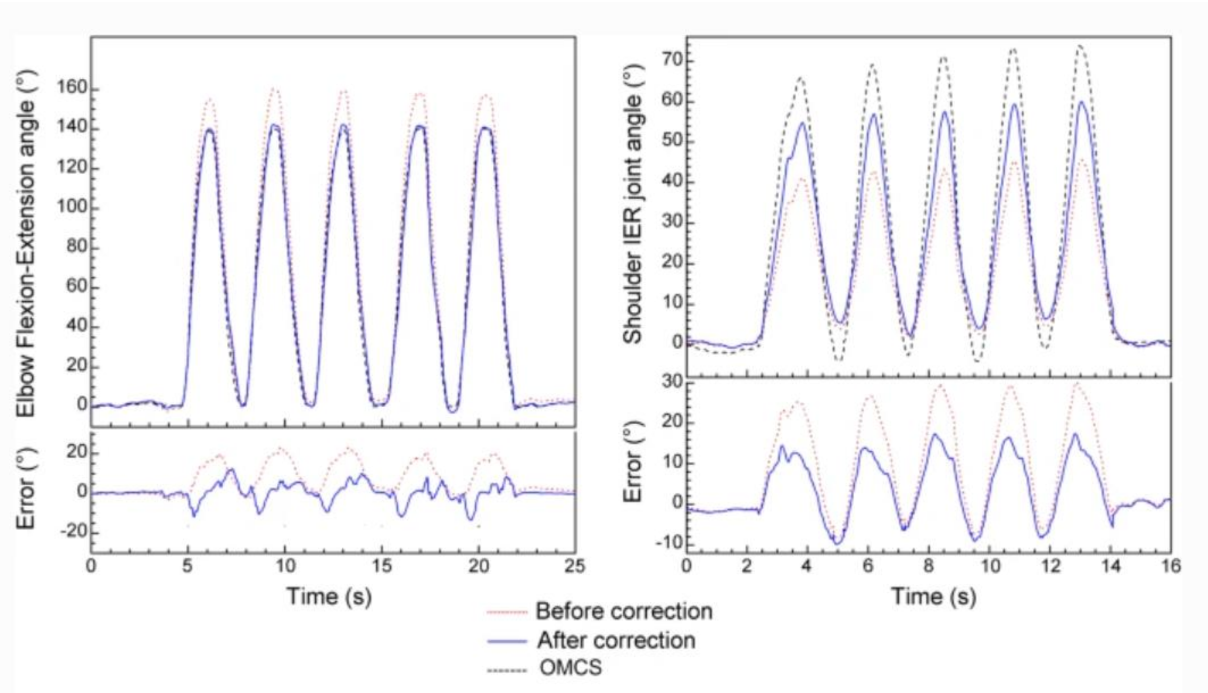
IMU sensor to detect the pelvis angle



IMU-based sensor-to-segment multiple calibration for upper limb joint angle measurement

IMU sensor net can be used to synchronically record and analyse the body part movement and cooperation.



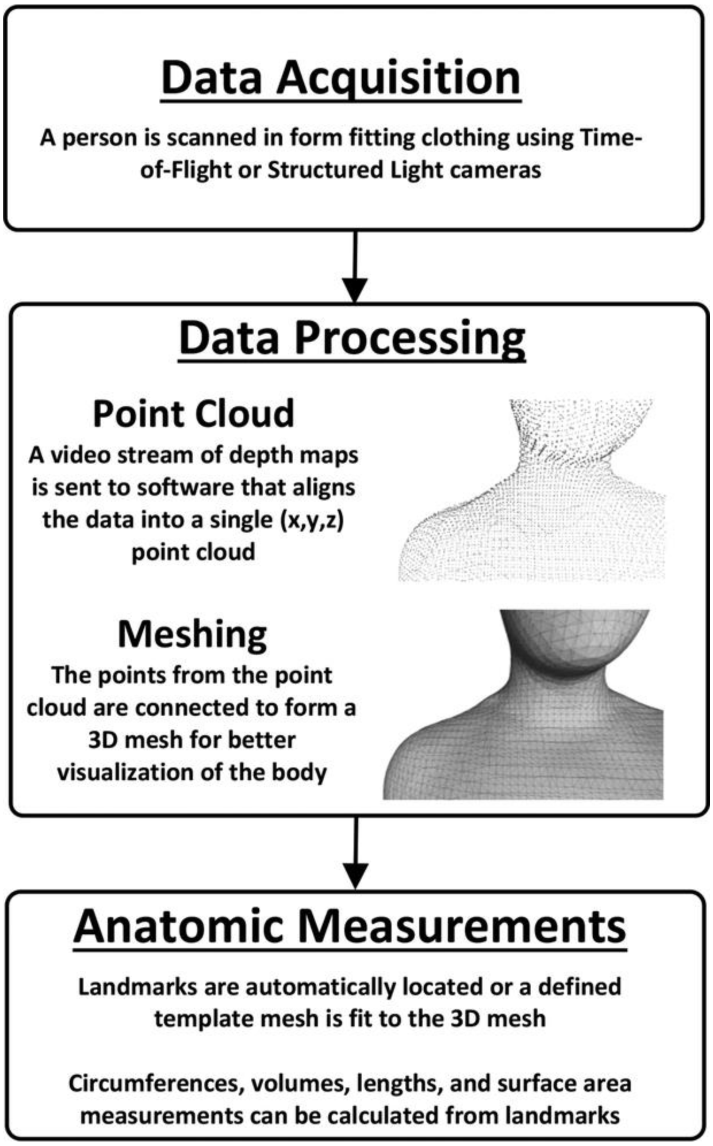


Example of elbow joint improvement assessment based on IMU sensor net monitoring.

Digital Anthropometry – review of modern electronic methods and measurement systems with computer data logging.

Three-dimensional scanners aim to create a high-quality representation of the whole human body surface using non-invasive optical methods. Because they rely on visible and infrared light (IR), 3D scanners capture information only from the surface of the body. This type of scanner is inexpensive and does not involve ionizing radiation, unlike other whole-body imaging methods such as computed tomography (CT) and dual-energy X-ray absorptiometry (DXA). For many day-to-day applications, such as estimation of % fat, 3D scanners hold significant advantages over more costly or invasive technologies.

From a technical standpoint, obtaining useful information from 3D scans occurs in three steps: **data acquisition, data processing, and anatomical measurement**



Types of data acquisition systems:

Structured Light Scanners. These systems utilize controlled visible or IR illumination patterns projected across the imaging field of view. One or more cameras measure deformations in the light pattern over objects (e.g. a human body) in the scene. This deformation information can be used to calculate per-pixel distance between the camera and the object and thus create a depth image using geometric triangulation.

Time of Flight (ToF) Scanners. These systems also employ coupled scene illumination (visible light or IR) and image recording using charge-coupled device or complementary metal-oxide semiconductor (CCD and CMOS) sensors. However, instead of measuring pattern deformations, ToF scanners quantify the round-trip time (RTT) for reflected photons to reach the image sensor in order to calculate depth. Previously used primarily for architectural and surveying purposes, ToF technology has become more broadly accessible with the introduction of the second-generation Microsoft Kinect. This technology is also used in the Styku S100 (Styku, LLC, Los Angeles, CA).

Scanner Technology Comparison

In general, structured light sensors have seen the broadest development due to their use of relatively inexpensive components (i.e., IR illumination source, conventional red-green-blue image sensors). Several manufacturers offer IR structured light sensors priced on the order of hundreds of dollars. The technique is well characterized and has been shown to be highly reliable.8 One disadvantage of structured light sensors is the challenge of multi-device interference when numerous sensors are used in parallel. Overlap between the projected illumination patterns from each sensor introduces noise in depth measurements.9 Historically, ToF technology has been less accessible due to the need for specialized high-speed circuitry. ToF sensors typically offer high frame rates and true depth measurement at each pixel, whereas structured light scanners may require some degree of interpolation in areas not covered by the scene illumination pattern. However, ToF sensors typically have significantly lower spatial resolution than similarly-priced structured light sensors due to their vastly higher data readout speed requirements.

Other technologies, including laser line scanning and millimeter wave imaging, have also been applied to 3D body surface imaging. These technologies have been adopted mainly in specific industrial and security applications as their higher costs prohibit widespread use in health-oriented settings.

Comparative conclusions of classical and modern measurement systems – the importance of precision reliability and validity of anthropometric data.

When studies require the gathering of anthropometric data for the design of new products it is very important to ensure that the results appropriately reflect the characteristics of the studied population. The importance of precision, reliability and validity of anthropometric data has been frequently studied however, reports on physical measurements in human populations frequently do not include estimates of measurement errors. Reliability and the appropriate representation of the reality is also crucial when using new measuring techniques and equipment. In this case it very important that the results obtained are close to the real value and are similar to the already proven methods. Most importantly, whatever the application or method used, the measurement of the human form needs to be practical and accurate.

Until recently, anthropometric measurements have been limited to traditional manual techniques, using anthropometers, calipers and measuring tapes. These techniques are simple to use and inexpensive but they also have some inherent limitations. Among these are: need for careful equipment calibration and trained observers; time-consuming nature of multiple measurement acquisition; and participants' compliance.

According to recent studies, traditional anthropometry is usually the most error prone and with the lowest correlation coefficients when compared with other measuring techniques.

4. Key ideas

- Anthropometric measurements are covered by standards for parameters and procedures.

- The development of technology supports anthropometric measurements with electronic systems allowing automatic data logging into IT systems.

- Introduction of new measurement devices and systems must take into consideration first of all importance of precision, reliability and validity of measured anthropometric data.

5. References

[1] Babiarczyk B, Turbiarz A. Body Mass Index in elderly people: Do the reference ranges matter? Prog Health Sci. 2012;2(1):58–67. 21. Vague J. A determinant factor of the forms of obesity. Obesity. 1996;4:201–203.

[2] Bray GA. Medical consequences of obesity. J Clin Endocrinol Metab. 2004;89(6): 2583–2589. http://press.endocrine.org/doi/full/10.1210/jc.2004-0535.

[3] Lee JS, Aoki K, Kawakubo K, Gunji A. A study on indices of body fat distribution for screening for obesity. J Occup Health. 1995;37:9–18.

[4] Hsieh SD, Yoshinaga H. Abdominal fat distribution and coronary heart disease risk factors in men-waist/height ratio as a simple and useful predictor. Int J Obes Relat Metab Disord. 1995;19(8):585–589.

[5] Ashwell M, Lejeune S, McPherson K. Ratio of waist circumference to height may be better indicator of need for weight management. BMJ. 1996;312(7027):377.

[6] Browning LM, Hsieh SD, Ashwell M. A systematic review of waist-to-height ratio as a screening tool for the prediction of cardiovascular disease and diabetes: 0•5 could be a suitable global boundary value. Nutr Res Rev. 2010;23(2):247–269.

[7] Ashwell M, Hsieh SD. Six reasons why the waist-to-height ratio is a rapid and effective global indicator for health risks of obesity and how its use could simplify the international public health

[8] Borrell LN, Dallo FJ & White K (2006): Education and diabetes in a racially and ethnically diverse population. Am J Public Health 96: 1637– 1642.

[9] Jones PRM, Rioux M. Three-dimensional surface anthropometry: Applications to the human body. Opt Laser Eng 1997; 28(2): 89–117.

[10] Lerch T, MacGillivray M, Domina T. 3D Laser Scanning: A Model of Multidisciplinary Research. Journal of Textile and Apparel, Technology and Management 2007; 5(4): 1–22.

[11] Scharstein D, Szeliski R. High-accuracy stereo depth maps using structured light. 2003 IEEE Computer Society Conference on Computer Vision and Pattern Recognition, 2003.

[12] Zhang ZY. Microsoft Kinect Sensor and Its Effect. IEEE Multimedia 2012; 19(2): 4–10.

[13] Cui Y, Schuon S, Chan D, Thrun S, Theobalt C. 3D shape scanning with a time-of-flight camera 2010 IEEE Conference on Computer Vision and Pattern Recognition (CVPR); 6 2010; San Francisco, CA, USA IEEE, 2010.

[14] Salvi J, Fernandez S, Pribanic T, Llado X. A state of the art in structured light patterns for surface profilometry. Pattern Recogn 2010; 43(8): 2666–2680.

[15] Sarbolandi H, Lefloch D, Kolb A. Kinect range sensing: Structured-light versus Time-of-Flight Kinect. Comput Vis Image Und 2015; 139: 1–20.

[16] Horaud R, Hansard M, Evangelidis G, Menier C. An overview of depth cameras and range scanners based on time-of-flight technologies. Mach Vision Appl 2016; 27(7): 1005–1020.

[17] Congdon NG, Youlin Q, Quigley H, Hung PT, Wang TH, Ho TC & Tielsch JM (1997): Biometry and primary angle-closure glaucoma among Chinese, white, and black populations. Ophthalmology 104: 1489– 1495.

[18] Eysteinsson T, Jonasson F, Arnarsson A, Sasaki H & Sasaki K (2005): Relationships between ocular dimensions and adult stature among participants in the Reykjavik Eye Study. Acta Ophthalmol Scand 83: 734– 738.

[19] Jonas JB, Xu L & Wang YX (2009): The Beijing Eye Study. Acta Ophthalmol 87: 247– 261.

[20] Lee KE, Klein BE, Klein R, Quandt Z & Wong TY (2009): Association of age, stature, and education with ocular dimensions in an older white population. Arch Ophthalmol 127: 88– 93.

[21] Lim MC, Lim LS, Gazzard G, Husain R, Chan YH, Seah SK & Aung T (2006): Lens opacity, thickness, and position in subjects with acute primary angle closure. J Glaucoma 15: 260– 263.

[22] Mohan V, Shanthirani CS & Deepa R (2003): Glucose intolerance (diabetes and IGT) in a selected South Indian population with special reference to family history, obesity and lifestyle factors – the Chennai Urban Population Study (CUPS 14). J Assoc Physicians India 51: 771– 777.

[23] Ramrattan RS, Wolfs RC, Hofmann A, Jonas JB & de Jong PTVM (1999): Determinants of optic disk characteristics in a general population. The Rotterdam Study. Ophthalmology 106: 1588– 1596.

[24] Saw SM, Chua WH, Hong CY, Wu HM, Chia KS, Stone RA & Tan D (2002): Height and its relationship to refraction and biometry parameters in Singapore Chinese children. Invest Ophthalmol Vis Sci 43: 1408– 1413.

[25] Tomidokoro A, Araie M, Iwase A & Tajimi Study Group (2007): Corneal thickness and relating factors in a population-based study in Japan: the Tajimi study. Am J Ophthalmol 144: 152– 154.

[26] Wang YX, Xu L, Jonas JB, Li JJ & Yang H (2008): Non-glaucomatous optic nerve damage and mortality associated in the Beijing Eye Study. Acta Ophthalmol 86: 923–924.

[27] Wong TY, Foster PJ, Johnson GJ, Klein BE & Seah SK (2001): The relationship between ocular dimensions and refraction with adult stature: the Tanjong Pagar Survey. Invest Ophthalmol Vis Sci 42: 1237– 1242.

[28] Wu HM, Gupta A, Newland HS, Selva D, Aung T & Casson RJ (2007): Association between stature, ocular biometry and refraction in an adult population in rural Myanmar: the Meiktila eye study. Clin Experiment Ophthalmol 35: 834– 839.

[29] Xu L, Li J, Wang Y & Jonas JB (2007): Anthropomorphic differences between angle-closure and open-angle glaucoma: the Beijing Eye Study. Acta Ophthalmol Scand 85: 914– 915.

[30] "STEPwise approach to surveillance (STEPS)". World Health Organization. 2012.

[31] "Waist Circumference and Waist-Hip Ratio, Report of a WHO Expert Consultation" (PDF). World Health Organization. 8–11 December 2008.