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Review Article

Anthropometry: As A Tool in Learning Living Anatomy

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Abstract: Anthropometry is a branch of science dealing with measurement of the human body in terms of the dimensions of bone, muscle and adipose (fat) tissue. It dates back to 1st century B.C. Vitrivius, Leonardo da vinci, Quetelet, Elsholtz are only a few out of several pioneers in the field of anthropometry. There are various methods and instruments developed by them in anthropometry. Methods involved in measurements gradually taken its course with the introduction of new instrumentation. Use of palms for measurements now shifted to digital callipers. Applications of anthropometry are wide in the field of anatomy. Living anatomy, gross anatomy, clinical anatomy, developmental anatomy, genetics, comparative anatomy are some of the branches that involve direct or indirect applications of anthropometry. Recent advances in anatomy involve the introduction of 3D virtual models. Appropriate measurements of various parts of human body are an essential factor for creating virtual life like models. It is a simple field of science that involves non-invasive techniques essential for understanding anatomical, functional and developmental patterns that are essential for human wellbeing. Out of many uses in anthropometry there are certain draw backs worth mentioning. This article gives a brief consideration of scientists, methods and instrumentation with limitations of anthropometry.
Keywords: Anthropometry, Anatomy

INTRODUCTION:

One of the most interesting and far reaching branches of science is Anthropology. Anthropology is vaguely defined as 'Science of man'. The recognized main subdivisions of Anthropology are: Archaeology, or the study of man's products and material accomplishments in the past; Ethnology, or the study of man's intellectual, linguistic, and present material activities; and Physical Anthropology, or the study of racial anatomy, physiology, and pathology. Anthropometry is a branch of physical anthropology that deals with the study of the measurement of the human body in terms of the dimensions of bone, muscle and adipose (fat) tissue. The measurements maintain their conformity with the anatomical landmarks and usually noted either in a laboratory set up or in a field. Anthropometry is more commonly used in cross sectional and longitudinal studies to quantify and analyze human variation.

Beginning of Anthropometry:

- Vitruvius 1st Century B.C in 'Ten books on architecture' mentioned that "In the human body there is a kind of symmetrical harmony between forearm, foot, palm, finger and other small parts; and so it is with perfect buildings." . He showed that the 'ideal' human body fitted precisely into both a circle and a square, and he thus illustrated the link that he believed existed between perfect geometric forms and the perfect body. Those drawings were called 'The canon of proportions' or 'The proportions of man'. Thus the study of anthropometry dates back to the time of Vitruvius.
- Measurements of human body in olden times were mainly meant for the figurative arts. Long ago during the period of Renaissance the artists of ancient Egypt and Greece formulated some standard criteria for the human body. The main aim of the then artists and naturalists was to produce a figurine of human being accurately in terms of body proportion but they failed. Their pictures did not really match with the actual proportions of a

man. Later on during the period of Greek civilisation, Polykleitos was the first to study in detail about the human body and wrote a book for the first time on artistic anatomy. The measurements of the foot to build a human figure from Egyptians gradually changed to the width of the hand at the metacarpophalangeal joints in Greece.

- Leonardo da Vinci [1] of fifteenth century concentrated his most of the works basing on the principles of Vitruvius and Polykleitos. Being an artist of Roman civilization period he was a keen observer to understand the structural and functional capabilities of human. He not only dealt with art but also dissected cadavers and made a note on his drawings. After his death many of his manuscripts had been neglected for a long time and later split up and dispersed. Only thirteen of his manuscripts in the form of note books were recovered and are available currently. Leonardo, a polymath, had intense interest towards human anatomy. His works were strongly influenced by Mondino de' Luzzi (c.1270–c.1326), Galen, the ancient Greek medical writer, and Avicenna, the great Arab philosopher and physician. Vitruvian man [2] was one of his most renowned works wherein he succeeded in understanding what is now called classical anthropometry. He was the one who correctly rendered the picture of a child or an adult man for the first time.
- Albrecht Durer applied the mathematical rules to the human proportions.
- Later on by 19th century criminologists, anthropologists and eugenecists like Alphonsoe Bertillon and Francis Galton developed more complex and mathematical representational strategies to measure human body. Bertillon was a considered to be the first forensic expert. Being a police officer he introduced many methods of anthropometry to make a record of criminals. He believed that people who were liable to reoffend could be identified through physical characteristics, and that people with certain characteristics were more likely to be criminals. He was the friend of surgeon and anthropologist Broca from where he borrowed ideas about physical measurements. In 1881, Bertillon developed techniques and instruments to measure individual features that would not change, for example eye colour, the shape and angles of the ear, brow and nose, and the distances between them. He also used photography technique to collect vast data of criminals. This systematic method was then popularised as 'Signaletics' or 'Bertillon age'. The system required rigorous training, highly competent technicians and was expensive. The measurements were to be taken repeatedly to achieve accuracy and precision. The data would vary as the person grows in age. By keeping all these points in view governments of Great Britain, Europe and America slowly abandoned this system and adopted the methods of finger printing and photography. Bertillon also improved the technique of 'metric photography', which used measured grids to document the dimensions of a particular space and the objects in it.
- Francis Galton was the cousin of Sir Charles Darwin who proposed 'Theory of Evolution'. He was interested in theories of heredity.
- In 1885 conducted 'Anthropometric Laboratory' and was the first man to conduct studies on measuring mental status of an individual by introducing Psychometrics. The purpose of the laboratory was to maintain a methodical register of the principal measurements of each person to obtain timely warning of remediable faults in development or to learn their powers. He realised that statistical investigation of data would be reliable only with large sample sizes [3].
- Quetelet: Adolphe Quetelet (1796–1874) [4] was a Belgian polymath and polyglot, who developed a passionate interest in probability calculus that he applied to study human physical characteristics and social aptitudes. During world war-II as the death toll was increasing gradually due to cardiac diseases and diabetes the reason behind the mortality was the major subject of concern. Quetelet devoted his work on cross sectional studies on weight and height of individuals. He finally concluded that spurts of growth after birth would be based on Quetelet index in 1832. According to Quetelet index 'the weight increases as the square of the height'. He was the first person to construct height and weight tables by applying his mathematical knowledge on the physical features of man. His interest evolved from the study of averages (physical characteristics), to rates (birth, marriage, growth) and ultimately distributions (around an average, over time, between regions and countries). Thus he contributed much to the field of statistics by proving Gaussian distribution was typical throughout nature, applied equally to physical attributes of humans, including body parts, derived from large-scale population studies. In 1960s the significance of Quetelet index in relation to obesity became evident. Later it was Ancel Keys who coined the term body mass index (BMI) in 1972.

- The first time photography was used to support the monogenecist or Darwinian account of human development was when British anthropologists Thomas Henry Huxely and John Lampey developed guidelines for the anthropometrical photographing of 'native subjects'. 1860s had witnessed a growth in racial type photographs produced by anthropologists, travellers & commercial photographers. They depicted cultural rather than biological differences and were not useful for making physical comparisons. When the anthropologists were concerned with 'vanishing races' due to the risk of dying out intelligent races of Europe in the evolutionary race of survival, there arose the urgent need for systematic racial photography.
- The term Anthropometry was introduced by a German physician Johann Sigismund Elsholtz (1623-1688) in mid seventeenth century in his manual called 'Anthropometria'. This term got its significance later on in eighteenth and nineteenth centuries [5]. It referred to a system of measuring the living human body to determine its respective proportions at different ages, or of physically distinguishing the human races so as to establish their evolutionary status relative to one another. He devised an instrument 'anthropometron' which may be a prototype of modern anthropometer. It consisted of a vertical rod and a sliding horizontal rod called "regula". This was probably devised after inspiring from an image drawn by Alberti showing a device used for measuring a figure in order to transfer those measurements to clay or stone.
- As defined by the French anthropologist Paul Topinard (1830-1911), the modern term anthropometry refers to a system of measurement of the living human body (and cadaver) to determine its respective proportions not only "at different ages, in order to learn the law of relative growth of the (body) parts," but also" in the (human) races, so as to distinguish them and establish their relations to each other". Thus the interest on quantitative measurements for clinical activities came into existence.
- There arouse two main schools of thought – French and German constitutional schools [6]. German school of thought was based on series of visceral investigations on cadavers and did not enable the physician to estimate the anatomical basis of constitution and the functional anomalies in livings. French school of thought was based on morphological features but did not concentrate much on predisposition of diseases.
- In India during the British rule anthropometry was used for the first time by Chor Herbert Hope Risley. He separated Aryans from non-aryans basing on nasal –index [7]. This was the first well known anthropometric study conducted in India. Mainly three groups of Indian population were distinguished as leptorrhine where people has fine nose with width less than 70% of length, platyrrhine are those with broad noses in which nasal index rises to greater than or equal to 85% and mesorrhine with medium noses having index value between 70 to 85. This classification made by him was to separate people basing on physical types [8]. Later on evolutionary and ecological mechanisms of human variation over ruled ideas of typology in the second half of the twentieth century. International standards have been proposed to standardize the anthropometric data.

Before conducting anthropometry the points between which the measurements to be taken are marked. These reference points are of two types- fixed and virtual. Fixed points are always on the same part of the body. It is used for measuring linear dimensions like height, width, spans and circumference points of body land marks. The posture of the subject should be fixed and measurements are repeated to get the correct reading. Location of the landmark should be understood and marked precisely in order to duplicate the readings for a large population. These are meant for understanding physical characteristics of human in static condition. Such kind of measurement is called traditional or conventional anthropometry. These measurements are referenced to non-deflecting horizontal or vertical surfaces supporting the subject. Previously the head was considered to be the most important and complicated of the human body. There was special importance given for the measurements of head. This lead to a branch of anthropometry called 'craniometry'. Measurements were also taken on the skeleton and are considered separately as 'Osteometry'. Both craniometry and osteometry are also apart of anthropometry. Generally for the recruitment purposes in army or sports measurements are taken in static posture.

Virtual points are those which change in position basing on movement. They help in measurement and evaluation of different aspects of the human body in motion like reach and the angular ranges of various joints. The measurements are taken with the human body dimensional co-ordinates x, y, z with

respect to body land marks as reference points at work or motion in the work space. This category is called functional or dynamic anthropometry. Measurements of human motion were considered as a separate branch called 'Kinanthropometry'. This field provides the quantitative interface between physiology and anatomy.

The measurements on both these fixed and virtual points can be done directly or indirectly. Direct method of anthropometry uses the need of anthropometric instruments. Subject will be palpated with a gentle touch on the land marks to be measured. By using hypodermic pencil the markings on the body will be done with the subject standing or sitting in the fixed position. By using appropriate anthropometric instruments the readings are recorded. Photography technique is used for indirect method. Sometimes sensors are fixed on the land marks and the dynamic readings are recorded. With the help of software programmes the readings are noted. 3D anthropometry since last decade became a challenge with the advent of improved scanning techniques. Whole body scanners are available to note the anthropometric measurements where soft tissues are not compressed during data acquisition, row data acquisition is rapid (seconds), repeatability of measurements on the same subjects over time is unlimited.

Linear measurements can predict the anatomical segment differences. For example difference in upper limb length shows either short or long upper arm. Segment length has a profound effect on the joint action. Any difference in the lengths of weight bearing areas can influence the postural stability. Static measurements were initially started by Vitruvius. Vitruvius, the architect, says in his work on architecture "the measurements of the human body are distributed by nature as follows: 4 fingers make 1 palm; 4 palms make 1 foot; 6 palms make 1 cubit; 4 cubits make a man's height; and 4 cubits make one pace; and 24 palms make a man;" and these measures he used in construction of buildings. Keeping these in view Leonardo da Vinci depicted Vitruvian man in his art.

Dynamic measurements involve studies on joint range of motion. All the movable joints in our body have a normal range of motion. Anthropometric assessment of joint range of motion plays a crucial role in analysing the faults in joint mechanics. Movement is produced when certain force acts upon the lever. Movement depends on the force applied as well as the length of the segment involved on which the force is applied. Now in order to determine the movement anthropometric data to measure segment lengths and force applied is needed. Movements at any particular joint are not truly same for all individuals. This is due to variation in segment length. Naturally when the force applied increases than a normal limit the bones tend to deform or break.

Applications of Anthropometry in learning living anatomy:

Anatomy knowingly or unknowingly comes into the path of human during everyday life. In every activities, since we wake up till we sleep, like exercise, reading a paper, lifting the bucket, sitting, standing, walking, eating, writing, singing, playing, clothes we wear, shoes and what not are all somehow linked to anatomy of human body. Anatomy deals with the structure. A measurement of structure to compare it with the normal values is anthropometry. All the above said activities are routine but they can't be performed by all in the same fashion. This is due to variation which can be detected non- invasively with the help of anthropometry. This branch of science is useful in number of fields including sport medicine, physical education, medicine, eugenics ergonomics and bioengineering.

Anthropometric measurements:

Anatomy deals with human structure and anthropometry measures the human structure to understand the well being. Anthropometry not only helps in recording the measurements but also helps us to correlate the variations in functional perspective. Thus anthropometry raises to a step ahead and in no doubt it acts as a better tool in leaning living anatomy.

Gross anatomy:

Gross structure of the human body provides us the information about growth. Height and weight are the most commonly measured parameters and can be determined with great accuracy. Average value of child's height and weight determine the nutritional status. Stature forms an important identity of the individual. Stature correlates directly with other body parameters like head, trunk and limb lengths. Body weight measured does not differentiate between body fat and fat free body mass. Several indices have been proposed to relate height and body weight. At the present time for fat determination, the most widely used methods are BMI, weight for height, triceps skin fold thickness and waist circumference or waist hip ratio. BMI is the most practical way to evaluate the degree of excess body weight. Though BMI is a good predictor of adiposity it is not a direct measure and may overestimate fatness in short subjects or those with relatively high muscle mass. Body weight for height

measurement is preferred for clinical assessment of obesity or failure to thrive in children younger than two years.

In addition to height and weight there are many other parameters that can address wide range of problems. Skin fold measurements, circumferences and girths are also helpful to assess adiposity. Skin fold callipers are used to find out the skin fold thickness [9] at triceps, subscapular, biceps, iliac crest, supraspinale, abdominal, thigh, calf and midaxilla. Waist circumference & hip circumference are also used to find out the fat in relation to body composition. Girths (arm relaxed, arm flexed and tensed, waist, gluteal and calf) and breadths (biepicondylar humerus and femur) also predict the fat composition of the body. Girths can assess the muscle development. Determination of body fat becomes a major part in the studies concerned with sports, rock climbers, prediction of diseases like cardiovascular disease, diabetes, breast cancers etc., and obesity.

Lengths:

Length measurements for segments are crucial and help us to correlate the problem underlying in difficulty of work performance. Derived lengths and direct lengths are two different varieties that can be derived with anthropometry. Segment lengths in case of sports need a special mention. For example short arms in respect to height are very unlikely to make a long stroke style in swimming. Swimmers with short arms will become slower and less efficient by trying to match the strokes per length of long-armed swimmers. Length of the digits is also used as marker in the identification of diseases. 2D:4D digit ratio is used in prediction of diabetes, cardiovascular diseases [10], osteoarthritis [11] as well as in the assessment of birth weight [12] and even in estimation of male physical fitness [13].

Angles:

All the movable joints in our body have a normal range of motion. Anthropometric assessment of joint range of motion plays a crucial role in analysing the faults in joint mechanics. Measurement of angle at any joint explains us the possible range of motion occurring at that joint. Angle is measured directly by using goniometer. Using sensors or pressure platforms for angle measurement is an indirect method. Movement is produce when certain force acts upon the lever. Movement depends on the force applied as well as the length of the segment involved on which the force is applied. Now in order to determine the movement anthropometric data to measure segment lengths and force applied is needed. Movements at any particular joint are not truly same for all individuals. This is due to variation in segment length. Naturally when the force applied increases than a normal limit the bones tend to deform or break. Spasm, contractures, fracture, and dislocation are the common causes of motion restriction and muscle weakness. In uncomplicated muscle weakness, a joint may move through its normal range passively but not actively. Active and passive restriction is likely from a bony or soft-tissue blockage, and the atrophy present will be most likely from disuse. Upon passive movement, bone blocks will feel as abrupt inflexible stops in motion, while extra-articular soft-tissue blocks will be less abrupt and slightly flexible upon additional pressure.

Clinical anatomy:

Knowledge of anatomy is very essential in performing surgical procedures. Any kind of operation needs a careful surgical planning. Especially in the case of aesthetic plastic surgery a decisive factor in achieving success is entirely based on ethnic and racial asymmetries and variations. There arises the need for studies on different anthropometric variables of people in different age, gender, race, culture and geographical locations. Each race has its own beauty so as do each individual of that race. Racial and ethnic anthropometric studies contribute invariably in assessing the normative data for a specific group. Studies conducted by Fantozzi in 2013 on toroplastic surgery [14], Jayratne on craniofacial assessment [15], Khandekar in 2005, Heidari in 2014 on lip surgery [16, 17], Doddi in 2010, Tuncel in 2013, Sharma in 2014 on nasal surgery [18-20] are only a few to name.

Developmental anatomy:

Anthropometry acts as a major tool in assessing development of foetus. Studies conducted on anthropometric variables of mother and infant showed a close relationship. Newborn birth weight was positively correlated to the maternal parameters like height, weight and mid arm circumference [21]. Studies also focused on parameters that can identify malnutrition in pregnant women and their association with adverse birth outcomes such as low birth weight, pre-term birth and intra uterine growth retardation [22, 23].

Genetics:

The changes in the gene frequencies cause genetic variation and sometime cause variation in phenotypes (physical appearance, disease states, etc.).

Comparative anatomy:

Physical anthropologists work broadly on three major sets of problems: human and nonhuman primate

evolution, human variation and its significance, and the biological bases of human behaviour. Man has evolved from the ape like ancestor. Segment length measurements of fore limb and hindlimb suggest the decrease in intermembral index lead to bipedalism. Longer hindlimbs and shorter forelimbs make to relay weight on hind limbs thus favouring bipedal motion. Longer forelimbs in apes are an adaptive mechanism for arboreal life. Comparative morphological studies, particularly those that are complemented by biomechanical analyses, provide major clues to the functional significance and evolution of the skeletal and muscular complexes that underpin our bipedalism, dextrous hands, bulbous heads, outstanding noses, and puny jaws. Studies showed that the chimpanzee's toes resemble the fingers and thumb of the human hand more closely than do chimpanzee hands resemble human hands. In general dimensions, the ape's feet are greater in both length and breadth than humans.

The human foetus "of the 4th month" has relatively shorter legs than the chimpanzee, orang-utan or gibbon. Another difference in proportion is the size of the cranium relative to the face, which is larger in the human foetus than in the chimpanzee, orang-utan or gibbon. Body shape of the humans varies with those of more closely related primates such as gibbons or bears. Even the segment lengths vary within the humans who are in different climatic conditions. People of warmer climate have taller body segment lengths in comparison to those living in colder climates. Individuals of higher altitude have wide bodies, high body masses for stature, short limbs relative to trunk length and fore shortened distal extremities, whereas those of lower latitudes have relatively narrow bodies, low body mass in relation to stature, long limbs and long distal limb extremities [24].

Martin and his associates worked on the allometry to compare brain size with body weight in humans. Homo sapiens has a brain size about 20 times larger than would be expected for a basal insectivore of the same body size (if such a creature were to exist) and obviously stands out in relation to haplorhine primates, having a brain size about three times larger than typical haplorhines (such as the great apes) [25]. Some of the studies even found gender differences showing that male Homo sapiens show higher correlation between brain and body weight than do females [26].

Bioengineering:

Anatomical considerations are must in developing 3Dvirtual models. Standard anthropometric measurements are required to conduct simulations that help in human modelling. More advanced techniques like stereophotogrammetry or sonic digitizers are used to acquire standard geometric data rather than the traditional one. These simulations for different sizes are also needed in development of prostheses and ergonomics. Virtual images developed methods to estimate internal joint locations based on surface landmarks and the resulting joint locations are used to define posture based on a kinematic linkage representation of the body.

Limitations of anthropometric methods:

Measurements can be affected by the measurer's characteristics, methods used in the measurement and the measurement environment. Trained and skilled anthropometrists are needed to acquire data. In conventional method at the time of reading soft tissue compression is the major drawback. Once the subject departs after collection of measurements, there is no chance of error correction.

Summary:

Anthropometry was used in the beginning by the artisans, and by the artists. Later the studies on height and weight measurements were used to indicate the social and economic standard of living of an individual. They were done with a motto of eliminating the inferior race and employing the superiors in the army. Studies became systematic and advanced to be used in criminological and medico-legal identification. During the world war the research was directed to find out the cause of epidemiological diseases. Quetelet index ruled out the cause of cardiovascular disease. Gradually its importance in determining obesity was understood. When the anthropometric data was standardised they became invaluable aids to scientific research in physiology, anatomy and especially anthropology. They are used to some extent by medical men and dentists, to assist them in reaching diagnosis or tracing improvement in their patients. Due to advancement in technology 3D virtual models of human body were created. They help in understanding the biomechanics. Some of the measurements prenatal and post natal help in identifying genetic disorders. Automatic marking of anthropometric landmarks on 3D models were recently developed. Thus anthropometry is a science of miracle that is used in various fields to rule out the possible variation by using non-invasive

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