ANTHROPOLOGY AND ERGONOMY

Osman Muftić and **Diana Milčić**
Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb, Croatia

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Contents

Summary

As the introduction to this chapter a brief review of customary branching of anthropology into physical, linguistic, cultural, social and applied anthropology together with the biomechanics is given. The closest branch to the physiological anthropology seems to be physical anthropology, which is very often mentioned as bioanthropology, and also applied anthropology, but also in some way as applied biomechanics.

According to the meaning of the syntagma *physiological anthropology* this branch of biology dealing with functions and vital processes of living organisms or, their parts and organs, became with the joining of biomechanics very close to the main meaning of mentioned syntagma. From this point of view, physiological anthropology should have

the main scope to investigate various characteristics of the human beings (and other living systems), and how different parts or organs of an organism work together to achieve a particular function. For example, all kinds of human movement are consequence of muscle contraction that occurs through action of chemical messengers produced by nerves that supply the muscle. On the other side, the description of the human movement is the task of biomechanics, which depends among other on the distribution of the masses during the motion. On that way the complete motion is controlled by means of physiology of mind. Our biomechanical feeling of the forces is some kind of relation of our mind to the kinesthesis and proprioception, because man's sense of movement depends upon his own activity. Feeling of force is the only concept of sensory physiology that is used likewise in physics.

The chapter is concluded with some modest ideas of future possibilities in the field of physiological anthropology, such as the development of different new kinds of biomechanical models on a structure and function of the locomotive system of the human beings, involving anatomy, physiology, anthropometry and cybernetics.

1. Introduction

A task, such as the discussion about the division of the any scientific field, is in public opinion a very thankless job. Why is it so? This is surely because; we are more or less accustomed to divisions that are done before.

We are working in the field of the applied mechanics which is the branch of general mechanics, and it is not the part of physics at all. Particularly, we do work in applying of mechanics to the living systems and humans, what are biomechanics and ergonomics. Through these two subdivided forms of mechanics we are involved in anthropology. Now the question is: to which branch of anthropology belongs anthropology with biomechanics? In our opinion it should be this branch which is concerned with physiology, or physiological anthropometry and anthropology.

According to the accepted division, the chief branches of anthropology include: physical anthropology, archaeology, linguistic anthropology, cultural and social anthropology. There is also another specialty - applied anthropology that involves application of the other fields.

Physical anthropology, or as it is also sometimes called (but in our opinion – wrong): bioanthropology - implying under that the study of human physical characteristics, studying two of the most outstanding characteristics of human beings which are there- large brains and the ability to walk upright. Also in this branch of anthropology is studying physical differences among human beings as

- blood types
- effects of nutrition
- hereditary diseases and
- skin colors

Also, physical anthropology researches fossil remains from prehistoric times to trace the development of life. This kind of anthropology sometimes is called paleoanthropology.

The main idea for this work is not substantially in division of the fields in anthropometry into small houses according to their titles. Moreover, this is a free attempt to the possible branching into floating divisions towards the actual necessity.

Here, we will start with the discussion about the application of mechanics to the living systems or materials. Such an approach to mechanical analysis of living systems is different from the one used in engineering because of its functional complexity of the living systems.

Living systems are the construction of many organic systems, which we should study and also their interactions. Partially important is the interaction of the humans with its environment. The relationship between man and environment has always been a subject of investigation. Scientific studies on five senses have been carried out since the time of Aristotle. The history of man's knowledge development of senses is very interesting and widespread.

Humans communicate in two different ways. One is through contact with the outside world and another with their own bodies. The first way of communication is through five senses known as hearing, sight, smell, taste and touch; the second way through the proprioceptive system.

To describe the five senses and the proprioceptive system, modern physiology does classify first the five senses in the following order: *Audition*, *Olfaction*, *Taste*, *Vestibular* and *Vision*, and then: Superficial or cutaneous sensations served by cutaneous branches of spinal and certain cranial nerves represented as follows: *Cold* , *Pain*, *Touch* and *Warmth*.

The existence of the "sixth" sense or as it is also called "muscle sense" was postulated by Charles Bell (1826) based on the fact that the nerves which connect muscles with the spinal cord contain afferent as well as efferent fibers. During the subsequent years sensory receptors were discovered also in tendons, joints and connective tissues, so that the previous term was substituted by the term "sense of movement". The term was later introduced by the neurologists as "kinesthesis" which has remained popular among psychologists. As we know, "kinesthesis" includes today more then afferent impulses from muscles, tendons, joints and subcutaneous tissues. Among the bodily components which mediate the "sense of movement" is also included those whose disturbance through cerebral disease also interferes with the comprehension of speech. The "sixth sense" could also be named as the "sense of gravitation in space". For example, even if we are in a totally dark place, where we are unable to see hands moving up, we know where our hands exactly are relative to our body. This is obviously the question of mechanical sensation.

It is evident, that both kinesthesis and properioception are related to the experience of force that is derived from phenomenology in its range and scale as in mechanics. Basically, sensory and mechanical forces are thus comparable. Studies of muscle sense,

sense of movement, kinesthesis, and proprioceptive system raise the issue of the sensual basis of awareness of the limb and beyond that question of the experience of the body. Contemporary neurophysiology is unable to provide answers because of its virtually exclusive pre-occupation with histology, biochemistry, electrophysiology, and electron microscopy. Similarly, at the end of the nineteenth century, it was the matter of philosophy that once again assumed and played its role in the discussion on neuropsychiatry, partially after the collapse of materialistic understanding of the world.

2. Biomechanics as the one Possibility of the Physiological Anthropology

Biomechanical theory of the human or animal motion mostly is based on experiments in the course of measurements, places, velocities, accelerations, forces etc. To the data determined in this way in many attempts was applying of different mathematical or mechanical methods on top.

But, if an individual repeats a specific motion under almost similar conditions a certain numbers of times, the pattern of motion will be changed in a particular manner-partially if this repetition is aimed to learn the optimal motion for a certain specific kind of motion. What is optimized in such an adaptation process? For instance, it is possible to determine the *optimal* motion, under which term we suppose the motion yielding the maximal performance, then we must know anthropological parameters such as muscles strength, circumferences of joint movements, location of centers of gravities, kinematical lengths of body segments, masses and moments of inertia of the body segments that can be predicted to change certain values after specific training. Other examples of such an optimization process are the construction of optimal artificial limbs in finding of the most economic work motions.

To present the problem in a general way, we have to simulate the human body by using mathematical as well as experimental models. In that sense, determination of the body elements that will be able to be a model should be as the first step.

To set adequate biomechanical and mathematical model of the human body during its movement we introduce further suppositions.

a) We consider that the human body can be divided into a number of segments that we regard as a mechanism; the members of mechanisms are bones as supporting members and, muscles and nerves which are working members.
b) Those bone segments may be mostly considered as rigid bodies;
c) Then we suppose that these rigid bodies are connected by joints of possibly different types that constitute, as a whole, system of open kinematical chains as it is shown in the figure, which is able to become into closed form. This system has about 250 degrees of freedom. Mentioned joints are of different types according to their numbers of degrees of freedom;
d) The configuration of so supposed system relative to a chosen fixed reference coordinate system at any instant time t can be described by a certain numbers of functions $q_r(t)$ which are called the time functions of generalized coordinates of the system. A quantitative description of the motion of the partially conservative dynamical system involves the setting up the equations of motion which can be

theoretically done by using the Lagrange equations. If this is possible and carried out we obtain at most 250 second order differential equations, which must be solved simultaneously;

In some biomechanical analysis it is not necessary to consider all joints and all degrees of freedom. If there are equations of constraint defined on a system, then some of coordinates q_r are not independent, and in that case the number of differential equations reduces accordingly. But anyhow, the problem even if is restricted number of equations they remain very sophisticated and because of complexity we are not concerned with this question here. In this chapter we will analyze, comparing with mentioned possibilities, only simple models which will help us to understand the main ideas of modeling.

3. Biomechanical Anthropometry

Fundamental measures in the movement description are anthropological measures. Practically, in the so called "biological anthropology" (or may be “physiological anthropology”) we consider only static anthropometry, that is content about data on linear measures like the distance between two emphasized points on the body. Also in this group of data there are angles of the relative motion of the body parts, which we can call kinematical dates. Under the term "biomechanical anthropometry" we don't understand only the linear measures like above mentioned distances between two emphasized points, but here we include the segmental masses and their distribution with reference to chosen coordinate system, then dynamical moments of inertia reduced to the centers of gravity of each segment, and then reduced to the center of gravity of whole body. Further, what is very important to know is that emphasized points for the same segmental part are not of the same value. In dynamical anthropometry the emphasized points are centers of instantaneous relative rotation in-between two neighboring members. Also particular attention is given in biomechanical anthropometry to knowing these quantities as time functions.

In the existing and accessible literature there are a great many data about human dimensions mostly those that belong to static and kinematical anthropometry. In the literature mentioned data are usually divided at first by sex, and then they are divided into three or five groups according to statistical distribution. Sometimes such data are also divided by age.

Statistical distribution of the standing height of the German adult females derived by values of determined as 5%, 25%, 50%, 70% and 95%. For example for 5 percentiles that means, that to the value of 5% the respective height is 1511 mm, what means that 5% of females are lower, or that 95% females are higher from this value. If x is mean value of the height, and σ is standard deviation, then 5. and 95. percentiles are

$$P_5 = x - 1.645\sigma$$

$$P_{95} = x + 1.645\sigma .$$

In the human motion analysis, or for only the motion analysis of some body segments in which are present significant accelerations, besides the forces and moments, it is also necessary to know the positions of some points, their velocities and accelerations, then positions of the gravity centers, dynamical moments of inertia of the whole body.

The dynamical anthropomeasures could be divided into internal and external. Dynamical moments of inertia that are determined by means of outside borders of the body segments are external dynamical moments of inertia. Related to the internal masses distributions, during some relative motion between the body segments, different quantities of the muscles and bone masses are involved in motion relative to what we can see from the outside. Even, by internal dynamic measures the masses of the muscles are depending on relative motion and the time. A typical example could be motion of the arm of standing person. If the arm hangs freely then one group of the muscles belongs to the volume of the arm according to the outside borders. If arm moves to upstairs then in motion increasingly is involved a group of breast's and back's muscles together with shoulder blade. So we have motion of the system with the changeable mass during the motion as it is known internal dynamical moments of inertia are not yet enough investigated.

Above mentioned statistical distribution has in dynamical anthropometry some special meaning. We are saying here about percentile distribution, because such kind of distribution shows the percentage of the subjects in one population for some anthropometrical value that is larger or lower than the chosen value.

Determination of the human mass distribution and body's center of gravity as a whole, was known a few centuries ago. Borelli (1608 - 1679) used such a method. Talking about the methods of mass distribution that were developed, and consequently determination of the centers of gravity, we will start mentioning Fischer and Braun (1889). They used an approximate method which is known as "coefficient's method". They supposed the existence of fixed relations between length of body segment and its mass. From these relations they were able to determine canter of gravity, radius of inertia and, of course moment of inertia. Accuracy of this method was doubtful because those coefficients were determined only on three male cadavers.

Much more accurate results in stipulating of the human body mass distribution and respective segmental centers of gravity were determined by Dempster (1961). Division of the body segments by means of plunging of body segments into the tubs water that was squeezed out was the measure of the segment volume. The results of Dempster are compared with those of Braun and Fischer in Table 1.

Segment	Braun & Fischer .1889 %	Dempster. 1955 %
Foot	1.71 + 0.12	1.49 + 0.17
Head and trunk	53.02 + 2.87	57.35 + 2.17
All limbs	46.98 + 2.87	42.65 + 2.17
Upper arm	3.33 + 0.21	2.70 + 0.20

Lower arm	2.09 + 0.24	1.58 + 0.13
Hand	0.84 + 0.04	0.63 + 0.005
Upper leg	10.73 + 0.85	10.22 + 0.85

Table 1. Segmental mass as a part of whole body mass

3.1. Method for Determination of the Segmental Masses

As the method of the determination of segmental human body masses, also the masses moments of inertia, we used method of Donskij and Zatscijorskij (1979). This method is extended by suggestions of Muftić (1984) and Muftić, Keros & Božić (1992). The masses were calculated by means of the regression formula:

$$m_i = B_0 + B_1 M + B_2 h \text{ , kg}$$

where the B_0, B_1, B_2 are the regression factors calculated by statistical method on 100 examinees, M is the total mass of the body, h is the standing height of the individual subject in cm and m_i is analyzed segmental mass (Donskij, Zacjorskij, 1979)

Segment	B_0	B_1	B_2	R	σ
Foot	-0.829	0.0077	0.0073	0.702	0.101
lower leg	-1.592	0.031616	0.0121	0.872	0.219
upper leg	-2.649	0.1436	0.0137	0.891	0.721
Hand	-0.1165	0.0036	0.00175	0.516	0.036
lower arm	0.3185	0.01445	-0.00114	0.786	0.101
upper arm	0.25	0.03012	-0.0027	0.837	0.178
Head	1.296	0.0171	0.0143	0.591	0.322
upper*	8.2144	0.1862	-0.058	0.798	1.142
middle*	7.181	0.2234	-0.0663	0.828	1.238
lower*	-7.498	0.0976	0.04896	0.743	1.02

* means trunk. R - regression coefficient. σ - standard deviation.

Table 2. Regression factors for males after Donskij and Zatsciorskij
(* means trunk, R - regression coefficient, σ - standard deviation.)

segment	B_0	B_1	B_2	R	σ

Foot	-1,207	0,0175	0,0057	0,71	0,11
lower leg	-0,436	-0,011	0,0238	0,42	0,36
upper leg	5,185	0,183	-0,042	0,73	0,81
Hand	-0,116	0,0017	0,002	0,48	0,03
lower arm	0,295	0,009	0,0003	0,38	0,11
upper arm	0,206	0,0053	0,0066	0,27	0,21
Head	2,388	-0,001	0,015	0,24	0,49
upper*	-16,593	0,14	0,0995	0,64	1,47
middle*	-2,741	0,031	0,056	0,45	1,09
lower*	-4,908	0,124	0,0272	0,61	0,9

* means trunk, R - coefficient of regression, σ - standard deviation.

Table 3. Regression factors for females after Donskij and Zatsciorskij (* means trunk, R - coefficient of regression, σ - standard deviation.)

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Biographical Sketches

Osman Muftić, Ph.D., is professor emeritus at the Faculty of Mechanical engineering and naval architecture, University of Zagreb. In a period from 1960 to 1963 he worked in Design office for heating and air conditioning systems. Since 1963 he was elected as an assistant at Mechanical engineering faculty at Department of Applied Mechanics. In 1972 he defended his doctorial thesis. In 1976 he was elected as an assistant professor of mechanics at Faculty of Mechanical engineering and naval architecture of Zagreb, and in 1982 he was elected as a full professor at the same faculty. After arrival of democracy in Croatia in 1990 he was appointed as a minister of science and technology in the Government of Croatia, what he was one and half year. Since 1993 to 1996 he was the ambassador of the Republic of Croatia in the Islamic Republic of Iran. After that he came back to Croatia and returned himself to the Faculty where he still works in the field of mechanics, biomechanics and ergonomy. In his 44 years of the work he published independently or as a co-author more than 150 scientific papers, and about the same number of professional works.

Diana Milčić, Ph.D. Her research interests include biomechanics, ergonomics, quality control and design theory. As a scientific researcher or chief she participated in several national scientific projects. She is author of more than fifty scientific articles and mentor for several master theses. She has taken part in about thirty international and home scientific meeting.