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Dual X-ray absorptiometry for estimating the volume of the soft tissue in the human skull

Abstract The aim of this study was to analyze the relationship between soft and hard tissue measurements of the head so as to identify the range of soft tissues parameters that should be applied in forensic facial approximation. The study was performed on 85 healthy female volunteers with an age range of 35–45 years. Total and regional body composition analysis was undertaken with subjects in a recumbent position using dual X-ray absorptiometry. The head was defined from the inferior part of the mandible to the vertex. We found the range of total head soft tissue weight to be between 3.02 and 4.96 kg. The quantity of soft tissue applicable to Caucasian female subjects in good health was estimated by subtracting the weight of the brain (approximately 1.17 kg in a typical adult female) from these values. Thus, the minimum and maximum values of the soft tissue are 1.85 and 3.79 kg, respectively.

Key words Dual X-ray absorptiometry • Fat mass • Lean mass • Soft tissue • Bone mineral content • Bone mineral density.

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Introduction

The analysis of physiological and skeletal characteristics of a group of living individuals of known age, sex, and ethnic group may assist forensic facial reconstruction from skeletal residues. Comparison between the body composition of a standard population of known nutritional status and the skeleton under examination may allow the estimation of the physiological status of the individual during life [1]. By comparing cross-sectional studies obtained with radiological investigations using densitometry measurements, one can obtain the quantity of fat and lean tissue of the whole body or of selected parts such as the head [2]. The quantity of each tissue type in individuals with the same skull area has a maximum and a minimum limit associated with nutritional and health status. Establishing these soft tissue limits will reduce the error associated with soft tissue approximation in facial reconstruction.

Dual X-ray absorptiometry (DXA) is used to discriminate between two substances in a given system; however, in cases where more than two substances are present, the accuracy depends on the number of additional substances and their attenuation characteristics [3]. In body composition research, a two-component system is defined as consisting of hard tissue (i.e., bone) and soft tissue [i.e., fat mass (FM) and lean mass (LM)]. DXA is a safe and noninvasive technique for assessing body composition [4]. Using this technique, we can estimate components of the head, namely, FM, LM, bone mineral content (BMC, mass in grams of the inorganic calcified content of the bone), and bone mineral density (BMD, bone mass per unit of projected bone area in grams per square centimeter).

The objective of the present study was to investigate the relationship between soft tissue and hard tissue parameters of the head in living subjects and consequently to evaluate a range of values for soft tissue parameters, which can be applied in forensic facial approximation.

Table 1 Head measurements for all studied subjects (n=85) using dual X-ray absorptiometry

	Fat mass (kg)	Lean mass (kg)	Tissue mass (kg)	Bone mineral content (kg)	Bone mineral density (g/cm^2)
Mean	0.94	2.74	3.69	0.47	2.26
SD	0.30	0.33	0.32	0.06	0.27
Minimum	0.28	1.30	3.02	0.21	1.12
Maximum	2.04	3.48	4.96	0.57	2.72

Study population and methods

Population

The study population comprised 85 healthy female volunteers with an age range between 35 and 45 years. The study protocol was approved by the medical ethics committee of the University of Tor Vergata (Rome, Italy) and all subjects signed a consent form.

Measurements

For all participants, we performed a complete medical examination and measured anthropometric and body composition variables. Body weight (kg; participants in underwear, bare feet) was measured using a digital scale that was sensitive to the nearest 0.01 kg (Body Master, Rowenta, Germany). Height (m) was measured using a stadiometer. Body mass index (BMI) was expressed as weight/height^2 (kg/m^2). During DXA examinations, the subjects remained in recumbent position on the scanning table. The scans were made with Lunar DXA (Lunar, Madison, WI, USA) in the fast scanning mode using software version 3.6. Total and regional body compositions were analyzed. The head was defined from the inferior part of the mandible to the vertex. All scans were performed by one observer and selected and judged by a second observer.

Results

Data on head measurements for all studied subjects are shown in Table 1. On average, the total soft tissue in the head, which is the sum of FM and LM, was 3.69±0.32 kg and the total BMC was 0.47±0.06 kg. The total soft tissue includes the mass of the brain, which was found to be 1.17 kg on average for female subjects. Thus, the minimum and maximum values of soft tissue are given by:

Minimum value of soft tissue = 3.02–1.17=1.85 kg (Eq. 1)

Maximum value of soft tissue = 4.96–1.17=3.79 kg (Eq. 2)

Discussion

Soft tissue mass changes, according to the age and sex of the individual, will increase or decrease within maximum and minimum values, depending on the body development and health conditions. A limit is needed for fixed reference points (i.e., ethnic group, age, health state, and sex), for tissue that can expand or reduce itself, beyond which the living individual will not survive. The applicable soft tissue related to age, sex, and ethnic group will have variable values as the body grows, becomes older, or the health state changes. From Eqs. 1 and 2 we can deduce that the quantity of soft tissue applicable to a Caucasian woman aged between 35 and 45 years and in good health is between 1.85 and 3.79 kg, considering the whole head and not only the face.

We believe that this method could be very useful in facial reconstruction from skull residues. Our future aim is to subtract from these values the weight of internal organs of the head (tongue, oral floor, turbinates, nasal septum, tonsils, mucosa covering nasal and oral cavity) so as to straighten the range and limit it to the more characterizing structures of the head (nasal pyramid, lips, cheeks etc.).

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