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Original article

Markers of metabolic and cardiovascular health in adults: Comparative analysis of DEXA-based body composition components and BMI categories

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ABSTRACT

Objectives: To investigate how body composition components fit body mass index (BMI) categories and whether they could be considered as markers of metabolic and cardiovascular health.
Design: Prospective study.
Setting: A center for preventive medicine.
Participants: Six hundred and sixteen consecutive outpatients: mean age of 56.0 ± 10.0 years; 74.6% aged ≥50 years and 61.4% were females.
Measurements: Fat mass (FM) and muscle mass (MM) were obtained by dual energy X-ray absorptiometry analyses. Metabolically unhealthy individuals were defined as people with biological features of dyslipidemia, hyperuricemia, diabetes, and/or hepatitis steatosis. Documented hypertension and/or atherosclerosis of one major artery, at least, defined individuals with cardiovascular complications.
Results: According to BMI categories, 45.8% of the sample was of normal weight, while 19.2% and 16.5% were classified as overweight and obese. A total of 78.0% and 86.3% of overweight and obese individuals were metabolically unhealthy respectively, 46.8% and 52.6% of subjects classified into normal and underweight BMI categories were also diagnosed. Cardiovascular complications mainly concerned the two highest BMI groups (78.2%). In multifactorial analyses the overweight and obese BMI categories were predictive of health outcomes [respectively, odds ratio (OR) = 8.05, 95% confidence interval (CI): 4.23–12.07 and 5.74, 95% CI: 3.41–8.98]. FM and MM indexes were significantly associated with metabolic (OR = 1.30, 95% CI: 1.19–1.47; and 0.84, 95% CI: 0.78–0.91) and cardiovascular (OR = 1.22, 95% CI: 1.13–1.32; and 0.72, 95% CI: 0.65–0.80) health respectively, and FM/MM (respectively, OR = 15.45, 95% CI: 11.77–20.17; and 16.61, 95% CI: 10.49–21.33) as well.
Conclusion: Our findings suggest that FM and MM readouts are important measurements of nutritional status and they extend the analysis of its impact on health outcomes to all BMI categories. Moreover, they highlight the interest of measuring body composition in medical check-ups to predict metabolic and cardiovascular diseases.

Introduction

The question of how adult weight may influence the risk of metabolic and cardiovascular health and inversely may promote longevity has profound health, social, and economic implications for individuals, communities, and the population as a whole [1]. In almost all epidemiological studies, the degree of overweight is simply defined by means of the body mass index (BMI) or Quetelet's

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index [2]. Expressed as the relationship between the total body mass (in kg) and stature (in m^2), it is the most widely used indicator of nutritional status in the general population. It was in 1997 that a World Health Organization consultation on obesity defined pre-obesity (overweight) as a BMI ≥ 25 kg/m^2, and class I, II, and III obesity as BMI ≥30, 35, and 40 kg/m^2 respectively.

BMI has, however, some limitations in estimating health-related risks [2,3]. Indeed, the relationships of the total body weight and the development of major health complications are strongly linked to the degree of adiposity. However, while it appeared obvious to establish normal weight as a function of height, this measurement accounts only for about two-thirds of the between-individual variation in total adiposity [4]. Furthermore, BMI does not account for sex, age, and fitness differences in fat mass (FM) even at the same body weight [5,6]. In addition, with aging, the decrease in stature, accumulation of fatty tissues, and reduction in lean mass (*i.e.* bone + muscle mass) further consider BMI as a problematic readout of total body weight and its health-related risks [1].

Dual energy X-ray absorptiometry (DEXA) is becoming a validated, reliable, and safe technique to assess the body composition. It uses the equivalent of less than 10% of one day's exposure to natural background radiation (0.001 mSv) which corresponds to lower level of radiation than a standard X-ray (0.1 mSv) [7]. Thus, the present study aims to analyze how the different DEXA-based body composition components [*i.e.* fat mass (FM) index, muscle mass (MM) index, and FM/MM] fit BMI categories and whether they could be considered as interesting markers of metabolic and cardiovascular health.

Materials and methods

Study population and design

The sample study was recruited at the Clinic of Genolier (Switzerland) and consisted of 616 consecutive ambulatory patients consulting the Center for Preventive Medicine (www.nescens.com) for a medical check-up between January 1, 2009 and December 31, 2012. Pregnant women and/or individuals with self-reported cardiac failure, who had a cardiac pacemaker, or who had previously undergone limb amputation were not considered. In addition, there were not any exclusion criteria.

Briefly, Nescens medical check-ups are designed in three steps. The first and third steps are dedicated to medical consultations, which are conducted before and after all the complementary investigations. The medical consultation conducted before is dedicated to personal and family medical histories, medications, current complaints and symptoms, and a complete medical examination is also performed. In the course of the first consultation, patients were informed about the protocol prior to signing informed consent. The results of the check-up are detailed and discussed during the second consultation. The second step is composed of biological, radiological, and functional investigations. Thus, blood test analyses, including in part the biological data of interest (see below and Table 1 for details), are carried out as well as a large panel of radiology exams such as DEXA-scan, angio-computed tomography (CT)-scans of the supra-aortic and coronary arteries, and total body CT-scan (256-row detector CT-scan). In addition, a cardiologist conducts a stress test on an electronically braked cycle ergometer in addition to a Doppler echocardiography. In order to avoid any interference due to injection of iodine-based contrast products used for the angio- and total body CT-scans, DEXA-scans were systematically carried out first. The data of interest were retrospectively collected from medical folders between April 1, 2013 and May 31, 2013. The study protocol was approved by the local ethics committee.

Data collection

Assessment of body composition

The assessment of body composition was performed with a DEXA scan (Hologic Discovery; Hologic Inc., Bedford, MA, USA) [8]. The instrument was calibrated by using a spine phantom daily and a step phantom weekly. All scans were performed 4–5 h after the last meal, at least, and before CT-scans. DEXA represents a three-compartment model for estimating body composition, because it can divide the body into three compartments: fat, bone mineral, and all other fat-free mass that does not include bone. Thus, unlike two-compartment models, DEXA is not subject to errors caused by variations in bone density among different ethnicities. DEXA thus provides bone density estimates, and regional estimates of body composition (*i.e.* it can estimate the body composition of individual parts of the body), by measuring the body's absorbance of X-rays at two different energies. Fat, bone mineral, and fat-free soft tissue have different absorption properties. As shown in Fig. 1, DEXA gets estimates of the body composition by scanning the entire body in 5–10 min. Data obtained were analyzed by a trained technician with an automated software (Vertec Scientific Ltd., Reading, BERKS, UK).

Body-composition variables chosen for the present study included two measures of total adiposity, namely the percentage of body fat and FM, and three measures of lean mass, namely percentage of body muscle, the bone mass, and MM. Subsequent to the measurement of individuals' height, height-adjusted indexes were considered. Thus, height raised to the power of 2 was used to calculate BMI [weight (kg)/height^2 (m^2)], FM index [FMI = FM (kg)/height (m^2)], and MM index [MMI = MM (kg)/height (m^2)].

According to BMI values, for descriptive purposes, individuals were classified as underweight (<18 kg/m^2), normal weight (18–24.9 kg/m^2), overweight (25–29.9 kg/m^2), or obese (≥30 kg/m^2) [1]. For statistical analyses, 18–24.9 kg/m^2 was used as reference group because it considers normal weight individuals. Body heights were measured to the nearest 0.5 cm and total body weight to the nearest 0.1 kg with calibrated digital scales (Seca Corp. Scale, Hamburg, Germany).

Biochemical markers

All biochemical markers considered in the study (see Table 1) were measured at the laboratory of the Clinic of Genolier (Synlab® Suisse – www.synlab.ch), which is accredited according to the international standards (ISO/CEI 15189 STS 497). Fasting blood samples were collected on peripheral venipuncture before all imagery investigations. Serum levels of total cholesterol (C), high-density lipoprotein-C, low-density lipoprotein C (LDL-C), triglycerides, and uric acid were measured using enzymatic methods with Combas Integra® 400 (Hoffmann-La Roche Ltd., Basel, Switzerland). Blood glucose was measured with hexokinase method; and blood glycated hemoglobin (Hb) A1c determined by IFCC (International Federation of Clinical Chemistry and Laboratory Medicine) standardized immunoturbidimetric method with Combas Integra® 400. The serum homocysteine and lipoprotein (a) levels were measured with nephelometric immuno-assays on latex particles using BN ProSpect® (Siemens AG, Munich, Germany) and Combas Integra® 400, respectively.

Outcomes of interest

Metabolic health

Metabolically unhealthy individuals were defined as participants who demonstrate biological features of dyslipidemia (*i.e.* total and/or LDL hypercholesterolemia and/or hypertriglyceridemia), and/or hyperuricemia and/or a diagnosis of diabetes defined as a level of HbA1c above 6.5% [9]. A diagnosis of hepatic