Available online at www.sciencedirect.com

Metabolism

www.metabolismjournal.com

Methods

Reproducibility and validity of ultrasound for the measurement of visceral and subcutaneous adipose tissues

Inga Schlecht[a,*], *Philipp Wiggermann*[b], *Gundula Behrens*[a], *Beate Fischer*[a], *Manja Koch*[c], *Johanna Freese*[d], *Diana Rubin*[e], *Ute Nöthlings*[d], *Christian Stroszczynski*[b], *Michael F. Leitzmann*[a]

[a] *Department of Epidemiology and Preventive Medicine, University of Regensburg, Franz-Josef-Strauss-Allee 11, 93053 Regensburg, Germany*
[b] *Department of Radiology, University Hospital Regensburg, Franz-Josef-Strauss-Allee 11, 93053 Regensburg, Germany*
[c] *Department of Epidemiology, Christian-Albrechts University of Kiel, Niemannsweg 11, 24105 Kiel, Germany*
[d] *Section of Nutritional Epidemiology, Department of Nutrition and Food Sciences, Rheinische Friedrich-Wilhelms-University Bonn, Endenicher Allee 11-13, 53115 Bonn, Germany*
[e] *Charité - Universitätsmedizin Berlin, Interdisziplinäres Stoffwechsel-Centrum, Augustenburger Platz 1, 13353 Berlin, Germany*

ARTICLE INFO

Article history:
Received 24 April 2014
Accepted 29 July 2014

Keywords:
Reproducibility
Validity
Ultrasound
Magnetic resonance imaging
Abdominal fat compartments

ABSTRACT

Background. Ultrasound represents a low-cost and widely available field method for assessing visceral adipose tissue (VAT) and subcutaneous adipose tissue (SAT) but its measurement properties are uncertain. The aim of the current study was to examine the reproducibility and validity of ultrasound to quantify abdominal fat compartments.

Methods. In two study centers, VAT and SAT thicknesses were quantified by ultrasound two times by two observers each among 127 adults aged 20–70 years. In a separate sample of 30 adults, the ultrasound method was validated by comparing VAT and SAT thicknesses with VAT and SAT areas at vertebrae L2/L3 as obtained by a single magnetic resonance imaging (MRI) slice.

Results. For VAT, the intra-rater reproducibility values for observers 1 and 2 were r = 0.996 (95% CI = 0.994–0.997) and r = 0.999 (95% CI = 0.999–0.999), respectively. For SAT, the intra-rater reproducibility values were r = 0.992 (95% CI = 0.989–0.994) and r = 0.993 (95% CI = 0.990–0.995), respectively. The inter-rater reproducibility values for VAT and SAT were r = 0.998 (95% CI = 0.997–0.999) and r = 0.990 (95% CI = 0.986–0.993), respectively. For VAT and SAT, the correlation coefficients between ultrasound and MRI measurements were r = 0.898 ($P < 0.001$) and r = 0.705 ($P < 0.001$), respectively.

Conclusion. Ultrasound provides reproducible and valid estimates of VAT and SAT and represents a useful method to assess abdominal fat in large scale epidemiologic studies.

Abbreviations: SAT, subcutaneous adipose tissue; VAT, visceral adipose tissue; BMI, body mass index; WC, waist circumference; WHR, waist-to-hip ratio; US, ultrasound; CT, computed tomography; MRI, magnetic resonance imaging; CI, confidence interval; ICC, intra-class correlation coefficient; SD, standard deviation; LOA, limit of agreement.

* *Corresponding author at:* Department of Epidemiology and Preventive Medicine, University of Regensburg, Franz-Josef-Strauss-Allee 11, 93053 Regensburg, Germany. Tel.: +49 941 944 5225; fax: +49 941 944 5202.
E-mail address: Inga.Schlecht@klinik.uni-regensburg.de (I. Schlecht).

http://dx.doi.org/10.1016/j.metabol.2014.07.012
0026-0495/

1. Introduction

Obesity is a major public health problem, the prevalence of which has doubled since 1980 in the developed and many developing parts of the world [1]. Obesity is a strong determinant of type 2 diabetes, hypertension, stroke, and numerous other chronic diseases, including several types of cancers [2–4]. Emerging research has targeted the distribution of fat in the body. Abdominal weight gain is manifested in the visceral and subcutaneous tissues, with visceral adipose tissue (VAT) considered to be more pro-inflammatory than subcutaneous adipose tissue (SAT) [5]. SAT has an independent anti-atherogenic effect and is associated with a higher level of insulin sensitivity and a lower risk for developing type 2 diabetes and dyslipidemia [6–9]. Currently, the gold standard for quantifying abdominal adipose tissue is computed tomography (CT) or magnetic resonance imaging (MRI). The use of these techniques in field settings is limited because of the associated costs, accessibility issues, contraindications, and possible adverse effects of radiation. Previous epidemiologic studies have used waist circumference (WC) and waist-to-hip ratio (WHR) to estimate abdominal fat and body fat distribution, respectively. However, those methods do not differentiate between VAT and SAT and therefore, cannot satisfactorily characterize body fat distribution patterns. A precise characterization of VAT and SAT is important for the assessment of risk of a host of major chronic diseases, such as cardiovascular disease, type 2 diabetes, and several types of cancer. Although ultrasound has been proposed as a suitable technique to accurately measure abdominal adipose tissue in research settings [5,10–12], previous validation studies of ultrasound have reported inconsistent results [10–22]. The aim of the current study was to evaluate an ultrasound-based quantification of VAT and SAT with regard to its feasibility, reproducibility, and validity.

2. Materials and methods

2.1. Study population

The reproducibility study was conducted between June and August 2011 in two cities in Germany and included a total sample size of 127 subjects who were randomly selected through the local population registries. One sample included 97 participants (55 women, 42 men) between 22 and 69 years of age living in a city in Southern Germany; the other sample comprised 30 subjects (16 women, 14 men) aged 20–70 years living in a city in Northern Germany.

The validity study was conducted between January and April 2013 in a separate sample of 30 subjects living in the southern German city. Subjects (16 women, 14 men) aged between 20 and 70 years were patients of the local hospital undergoing MRI examination of the abdomen or they were volunteers. The study protocols for all studies were approved by the ethics committee of the local hospitals, and all participants provided written informed consent.

2.2. Anthropometric measurements

Height and weight were measured with the participants wearing underwear without shoes. Body mass index (BMI) was calculated by dividing body weight (in kilograms) by height in meters squared (m^2). Waist circumference was measured at the midpoint between the lower rib and the iliac crest. Measurements were taken with the participant standing in upright position.

VAT and SAT were quantified using a Mindray DP-50 (at the southern study center) or GE Healthcare Logic 700 (at the northern study center) B-mode ultrasound machine with a 3.5–5.0 MHz convex array transducer. Study nurses with no prior experience in ultrasound were trained to perform the measurements according to a modified version of the protocol introduced by Stolk et al., who reported a reproducibility correlation coefficient of 0.97 ($P < 0.001$) [21]. Measurements involved multiple image planes that provided information on adipose tissue thickness. For all images, the transducer was placed on a marked position drawn at the cut-point between the left and right midpoint of the lower rib and the iliac crest on the median line of the abdomen. The measurement of VAT involved one individual image plane at the median line extending from the linea alba to the lumbar vertebra corpus. SAT was measured as a second image plane from the skin to the linea alba at the median line. All measurements were performed manually by the same examiner at the end of normal expiration applying minimal pressure without displacement of the abdominal contents as observed by the ultrasound image. The parameters assessed were extracted manually from the images with the electronic onboard caliper and were stored directly in a database.

MRI was performed with a clinical whole body 3T system (Magneton Sykra, Siemens Healthcare, Erlangen, Germany). Subjects were placed in supine position and three T1-weighted turbo spin echo, water suppressed, transaxial slices with a thickness of 10 mm were acquired and centered on the L2-L3 vertebral body as well as 10 mm above (L2-L3+) and 10 mm below (L2-L3–) by trained radiographers. The in-plane resolution was 1.3 × 1.3 mm, field of view 500 × 500 mm, repetition time = 400 ms, echo time = 21 ms, 2 averages, 3 concatenations. Areas of VAT and SAT were calculated using a semi-automated method and a threshold map in combination with manual input to distinguish between the VAT and SAT compartments. The software analyze 11.0 (BIR; Mayo Clinic, Rochester, MN) was used for calculations.

2.3. Reproducibility

In both study centers, the intra- and inter-rater reproducibility of the ultrasound method was assessed by examining each participant twice by two observers, each using the same examination protocol. The examinations were performed consecutively without any other examinations in-between. At the southern study center, the second observer was blinded to the results of the first observer to avoid information bias.

2.4. Validity

Because the ultrasound-based parameters are one-dimensional and the MRI measures are two-dimensional, the validity of ultrasound measurement to predict VAT and SAT cannot be directly assessed. Thus, in addition to the calculated area of VAT and SAT, MRI images of VAT and SAT thicknesses were determined using the *MicroDicom Viewer*. The VAT and