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● *Original Contribution*

ABDOMINAL FAT IN CHILDREN MEASURED BY ULTRASOUND AND COMPUTED TOMOGRAPHY

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Abstract—The prevalence of childhood obesity is increasing rapidly. Visceral fat plays an important role in the pathogenesis of metabolic and cardiovascular diseases. Currently, computed tomography (CT) is broadly seen as the most accurate method of determining the amount of visceral fat. The main objective was to examine whether measures of abdominal visceral fat can be determined by ultrasound in children and whether CT can be replaced by ultrasound for this purpose. To assess whether preperitoneal fat thickness and area are good approximations of visceral fat at the umbilical level, we first retrospectively examined 47 CT scans of nonobese children (body mass index <30 kg/m^2; median age 7.9 y [95% range 1.2 to 16.2]). Correlation coefficients between visceral and preperitoneal fat thickness and area were 0.58 ($p < 0.001$) and 0.76 ($p < 0.001$), respectively. Then, to assess how preperitoneal and subcutaneous fat thicknesses and areas measured by ultrasound compare with these parameters in CT, we examined 34 nonobese children (median age 9.5 [95% range 0.3 to 17.0]) by ultrasound and CT. Ultrasound measurements of preperitoneal and subcutaneous fat were correlated with CT measurements, with correlation coefficients ranging from 0.75–0.97 (all $p < 0.001$). Systematic differences of up to 24.0 cm^2 for preperitoneal fat area (95% confidence interval –29.9 to 77.9 cm^2) were observed when analyzing the results described by the Bland-Altman method. Our findings suggest that preperitoneal fat can be used as an approximation for visceral fat in children and that measuring abdominal fat with ultrasound in children is a valid method for epidemiological and clinical studies. However, the exact agreement between the ultrasound and CT scan was limited, which indicates that ultrasound should be used carefully for obtaining exact fat distribution measurements in individual children. (E-mail: v.jaddoe@erasmusmc.nl) **© 2009 World Federation for Ultrasound in Medicine & Biology.**

Key Words: **Adolescent, Child, Intra-abdominal fat, Ultrasonography, Validation study.**

INTRODUCTION

The prevalence of childhood obesity is increasing rapidly and is currently a major health problem worldwide (Lobstein and Frelut 2003; Lobstein and Jackson-Leach 2007). The prevalence in the United States increased from 10–13% between 2000 and 2004 (Lobstein and Jackson-Leach 2007). Also, the rate of annual increase has risen from 0.1% in the 1980s to 0.3% in the late 1990s (Jackson-Leach and Lobstein 2006). Childhood obesity is an important risk factor for developing metabolic syndrome in adulthood, including type 2 diabetes, and cardiovascular diseases (Dietz 1998). Epidemiological studies have shown that rather than high body mass index (BMI), visceral fat has an important role in the pathogenesis of several metabolic and cardiovascular diseases both in adults and children (Caprio et al. 1996; He et al. 2002; Klein 2004; Fox et al. 2007). The ratio between visceral and subcutaneous fat is significantly associated with several metabolic risk factors (Faria et al. 2002; Despres and Lemieux 2006). Visceral fat has been demonstrated to be correlated to insulin, cholesterol and triglyceride levels in children (Caprio et al. 1996; Gower et al. 1999). Furthermore, several plasma markers of adiposity such as interleukin-6 and adiponectin levels have been shown to be associated specifically with the amount of visceral fat (Ahima and Flier 2000). Therefore, rather

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than studying body mass index and obesity, we expect that studies focused on abdominal fat distribution in children will lead to better insight in the causes of adverse body composition and the consequences for development of metabolic and cardiovascular diseases.

Currently, computed tomography (CT) is considered a valid method to measure abdominal fat distribution (Borkan et al. 1982; Tokunaga et al. 1983; Yoshizumi et al. 1999). CT scanning cannot be performed easily in healthy children because of radiation exposure and is therefore unsuitable for epidemiological or clinical research purposes. Magnetic resonance (MR) imaging, which also allows very detailed information on fat distribution, is radiation free but is time consuming, strenuous for the child and expensive (Siegel et al. 2007). Alternatively, ultrasound is also radiation free and easy to perform in children. With ultrasound, preperitoneal fat can be measured, which is known to be an appropriate proxy for visceral fat in adults (Suzuki et al. 1993). However, these results cannot be extrapolated easily to young children.

Therefore, we set out to examine whether measures of abdominal visceral fat can be determined by ultrasound in children and whether CT can be replaced by ultrasound for this purpose. We first examined whether preperitoneal fat is a good approximation for visceral fat in children using CT scan comparisons. Then, we compared measures of subcutaneous and preperitoneal fat in children using abdominal ultrasound and CT methodology.

MATERIALS AND METHODS

Comparison visceral and preperitoneal fat in CT scans (substudy 1)

Design and subjects. All abdominal CT scans performed in the Radiology Department of the Erasmus Medical Center–Sophia Children's Hospital between January 2003 and December 2007 were retrospectively evaluated ($n = 424$). All CT scans were performed for medical reasons. For this study, the liver needed to be fully visible to calculate preperitoneal fat. Of these CT scans, 171 were excluded because of insufficient scan quality or an insufficient field-of-view, 113 were excluded because of abdominal anatomical abnormalities, such as ascites or abdominal tumors, 53 were excluded because of repeated CT scans of the same individual, 35 were excluded because children were older than 18 years and 5 were excluded because of obesity (BMI >30 kg/m^2). In total, 47 CT scans remained for analysis (29 boys, 18 girls, median age 7.9 y [95% range 1.2 to 16.2]).

CT scanning measurements. All CT scans were performed on a multidetector six-slice (Siemens Somatoscan, Erlangen, Germany) in the supine position. A pediatric radiologist determined the protocol used for scanning, including the field-of-view. To facilitate the procedure of measuring the thickness and area in CT data, we used an in-house developed semiautomatic drawing and measuring tool using MevisLab (Bremen, Germany) as software environment (MevisLab). This tool directly imports CT data, has various visualization and image interpolation options, and supports the drawing of lines and closed contours on, e.g., the transversal and sagittal planes. All measurements were performed offline, using linear interpolation, with a fixed window width and window level settings of 600 HU (Hounsfield units) and 100 HU, respectively. All CT measurements were performed by the same research assistant.

Intraabdominal visceral fat was determined in a transversal slice at the position of the umbilicus. A fixed range of HU was used to determine the fat area. Pixels with HU between –190 and –30 were defined as fat (Kvist et al. 1986). All area measurements were performed in a sagittal plane at the level of the umbilicus. The abdominal muscle wall was used as a contour for the intraabdominal tissue. The visceral fat area was determined by calculating the area of all pixels with an attenuation coefficient between –190 and –30 HU within the contour for the intraabdominal tissue. The total abdominal fat area was determined by calculating the area of all pixels with an attenuation coefficient between –190 and –30 HU in the entire sagittal plane. The subcutaneous fat area was calculated by subtracting the visceral fat area from the total abdominal fat area. Then, the ratio was determined between the visceral and subcutaneous fat areas.

Subsequently, the position of the maximum preperitoneal fat thickness was established. The maximum preperitoneal fat thickness is located at the upper part of the ventral side of the liver. In a transversal slice, the maximum preperitoneal fat thickness was measured (Fig. 1a). The thickness of the subcutaneous fat layer was measured at the same position. Then, an area of preperitoneal and subcutaneous fat was measured in a sagittal plane starting at the maximum preperitoneal fat thickness and measuring 20 mm in the caudal direction (Fig. 1b). Finally, preperitoneal-to-subcutaneous ratios could be calculated for both fat thickness and area.

Data analysis. To evaluate associations between visceral fat and preperitoneal fat, we calculated Pearson's correlation coefficients (r). We compared visceral fat with both preperitoneal transversal thickness and preperitoneal area. We also calculated correlation coefficients between the various subcutaneous fat measurements and between visceral/subcutaneous fat ratio and preperitoneal/subcutaneous fat ratio.