ORIGINAL ARTICLE

Possibilities of Ultrasound Measurement of the Amount of Visceral Fat in Obese Children

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ABSTRACT

Background. Metabolic complications of obesity are linked to excessive accumulation of visceral fat. Certain anthropometrical indicators are used in clinical practice to determine the distribution of fat. The aim of the paper is to find out whether there is any correlation in childhood between ultrasound investigation of the abdominal cavity (IAT) and selected anthropometrical and biochemical parameters.

Methods and Results. Ultrasound, anthropometrical and laboratory investigations were performed in 69 obese children (38 boys, 31 girls) aged 7 to 18 years. Their blood pressure was measured. Statistical evaluation involved correlation analysis and the calculation of Pearson's partial correlation coefficient. In boys with BMI 25–38.8 (over 97th percentile) a significant correlation was found between IAT and BMI ultrasound measurements ($r=0.44$, $p\leq0.06$), chest circumference ($r=0.45$, $p\leq 0.005$), waist circumference ($r=0.65$, $p\leq0.0001$), waist/hips circumference ratio (WHR, $r=0.61$, $p\leq0.0001$). A significant correlation was found between IAT and the subscapular fold ($r=0.45$, $p\leq0.005$), the front axillary fold ($r=0.55$, $p\leq0.0004$), suprailiac ($r=0.51$, $p\leq0.001$) and abdominal folds ($r=0.54$, $p=0.0004$). The correlations between skin folds of the extremities and IAT were not significant. In boys, unlike girls, triacyglycerol levels correlated with IAT ($r=0.41$, $p\leq0.01$); the relation between IAT and other metabolic factors was not confirmed in either sex. In girls (BMI 23.4–33.4, i.e. above the 97th percentile) positive correlations were found between IAT and BMI ($r=0.42$, $p\leq0.01$), chest circumference ($r=0.42$, $p\leq0.01$) and waist ($r=0.46$, $p\leq 0.009$). Correlation between IAT and WHR was not proven. Subscapular fat ($r=0.46$, $p\leq0.009$) and abdominal folds ($r=0.52$, $p\leq0.003$) correlated with IAT.

Conclusions. Ultrasound measurement is a useful and accessible method to determine the amount of visceral fat in childhood. There is a significant correlation between ultrasound measurement and selected anthropometrical parameters; this relation is more pronounced in boys than in girls.

Key words: obesity, visceral fat, metabolic complications, anthropometrical parameters, ultrasound investigation of the intra-abdominal space.

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Obesity is considered the most common metabolic disease both in adults and in children. The prevalence of obesity is increasing worldwide, both in developed and developing countries (1, 2). Complications caused by obesity have a significant impact on the quality and length of life of the individual. Obesity is a risk factor in a number of adult diseases, e.g. cardiovascular diseases, insulin resistance and diabetes, hyperlipidemia and hypertension (3, 4). Obese children have a higher risk of obesity in adulthood; it is therefore necessary to identify high-risk individuals and introduce preventive measures at as early a stage as possible in childhood (5, 6). Metabolic complications of obesity in adults are associated with excessive accumulation of visceral fat. The presence of visceral fat can be proven in children as young as 4 to 7 (7,8). In the pre-pubertal stage and in puberty the amount of fat is not significantly different in girls and in boys; in post-pubertal boys larger amounts of intra-abdominal fat can be demonstrated than in girls (7, 9, 10). Accurate investigation methods for the determination of the amount of intra-abdominal fat (CT, NMR, DEXA) are not suitable for common use because of their high price or radiation load and unavailability. That is why anthropometrical indicators (waist circumference, waist/hips ratio, thickness of central and peripheral skin folds, centralization index – i.e. subscapular to tricipital fold ratio) are used in clinical practice to determine fat distribution. It has been found that these selected anthropometrical parameters can serve as an alternative method to determine the amount of visceral fat (IAT), even though direct methods of measuring IAT correlate better with metabolic parameters. Another option of indirect determination of the amount of visceral fat in adults is ultrasound measurement of intra-abdominal depth (11, 12). The investigation is based on the measurement of the space between the internal margin of the abdominal muscle and the anterior wall of the aorta, which is filled not only with fat, but also with a number of organs. It has been found that its depth correlated significantly with visceral fat measurements executed by direct methods (12–14). There is little experience with ultrasound measurement of the intra-abdominal space in children (13, 14).

We tried to find whether there was a correlation in children between ultrasound investigation of the intra-abdominal space (IAT) and selected anthropometrical and laboratory parameters.

PATIENTS AND METHODOLOGY

In 1999–2002, 69 obese children (38 boys, 31 girls) 7 to 18 years of age were subjected to ultrasound, anthropometrical and laboratory investigation as a part of their first entrance interview at the Clinic of Pediatric and Adolescent Medicine of the General Teaching Hospital and the 1st Medical Faculty of Charles University. Secondary causes of obesity were excluded on the basis of patient history (drugs affecting body mass or body distribution of fat, earlier diagnosed genetic syndromes, endocrinopathy and other diseases associated with obesity). Children were always invited for the investigation at the same time, in the morning before eating. Blood was collected, anthropometrical parameters measured and the depth of the intra-abdominal space determined by ultrasound. All the parents were informed about the procedure and objective of the investigation and were asked to sign their informed consent.

Anthropometrical parameters

Body height and mass were determined using standard methods. BMI was calculated using the mass/height^2 (kg/m^2) formula. Body circumferences (waist, hips, thighs, arms) were measured using a flexible 1 centimeter wide measuring tape with 0.5 cm discrimination. The thickness of subcutaneous folds was measured with a Somet caliper, using Pařízková's method, at 10 standard anatomical sites. Blood pressure was measured in a sitting position, at rest, using a cuff of appropriate width.

Ultrasound measurement

Ultrasound investigation was always performed using the same machine (ATL Ultramark 9, probe 3.5 MHz). The distance between the anterior wall of the aorta and the internal surface of the musculus rectus abdominis was measured approx. 1 cm above the bifurcation of the aorta in the transversal section during slow expiration (11, 12).

Laboratory investigation

Glycemia, aminotransferase, uric acid, triacylglycerols and total HDL and LDL cholesterol, insulin and C peptide levels were determined after 12 hour nocturnal fasting.

Statistic evaluation

Correlation analysis and the calculation of Pearson's partial correlation coefficient adjusted to age were used for the statistical evaluation.

RESULTS

The characteristic of the group of investigated children is included in Table 1. Body mass index was compared with the respective percentile charts, and in all the children BMI was above the 97_{th} percentile in relation to chronological age (15). Table 2 gives the results of laboratory investigations and blood pressure values. Tables 3 and 4 present the results of the correlation of anthropometrical parameters with ultrasound measurement of the intra-abdominal space.

Boys

In boys with BMI 25–38.8 a significant dependence was found between IAT ultrasound measurement and BMI (r=0.44, p≤0.06), chest circumference (r=0.45, p≤0.005) waist circumference (r=0.65, p≤0.0001), waist/hips circumference ratio (WHR, r=0.61, p≤0.0001). A significant correlation was proven between IAT and the subscapular fold (r=0.45, p≤0.005), the fold in the anterior axillary line (r=0.55, p≤0.0004), suprailiac (r=0.51, p≤0.001) and abdominal fold (r=0.54, p=0.0004). The correlation between the skin folds of the extremities and IAT were not significant. The triacylglycerol level correlated with IAT (r=0.41, p≤0.01), a relation between IAT and other metabolic parameters was not confirmed (Tab. 5).

Girls

In girls (BMI 23.4–33.4, i.e. above the 97^{th} percentile) positive correlations between IAT and BMI (r=0.42, p≤0.01), chest circumference (r=0.42, p≤0.01) and waist (r=0.46, pp≤0.009) were also found. Correlation between IAT and WHR was not proven. IAT correlated with subscapular fatness (r=0.46, p≤0.009) and abdominal folds (r=0.52, p≤0.003). We have not proven a relation between IAT and metabolic parameters in girls (Tab. 5).

DISCUSSION

Metabolic complications in obesity are usually not demonstrable in childhood. Epidemiological studies nonetheless show

Tab. 1. Characteristics of the group of 69 obese children

	Boys (n = 38)			Girls (n = 31)		
	Average	SD	Range	Average	SD	Range
age (years)	12.8	3.2	7–18	12.4	2.76	7.5–18
height (cm)	161.6	16.29	129–194	154.7	15.31	113–175
weight (kg)	75.9	24.8	38.9–146	67.3	20.44	28.5–106.7
BMI (kg/m^2)	28.3	4.24	21.8–38.8	27.4	5.02	20.1–38.6
waist	90.7	12.87	75–125	83.2	12.71	63–106
IAT (cm)	4.5	1.27	1.9–7.7	4.6	1.33	1.4–9.0

IAT – intra-abdominal fat measured on ultrasound, BMI - body mass index, SD – standard deviation

Tab. 2. Results of biochemical parameters and blood pressure values in the group of 69 obese children

	Boys (n = 38)			Girls (n = 31)		
	Average	SD	Range	Average	SD	Range
BP systolic (mmHg)	125.9	16.8	100–180	122.8	18.04	90–180
TK diastolic (mmHg)	80	15.1	60–110	80	11	60–100
glycemia (mmol/l)	4.9	0.56	3.9–6.1	5.0	0.48	3.9–6.1
cholesterol (mmol/l)	4.6	0.89	3.1–6.6	5.0	0.77	3.5–6.6
HDL (mmol/l)	1.1	0.29	0.7–1.8	1.4	0.34	0.8–2.0
LDL (mmol/l)	2.9	0.75	1.7–4.5	3.0	0.7	1.4–4.4
TRG (mmol/l)	1.5	0.68	0.5–3.7	1.5	0.72	0.6–3.7
uric acid (umol/l)	378	92.74	209–606	335	72.19	210–520
insulin (mIU/l)	12.4	8.69	3.5–42	15.1	9.56	1.6–42.2
C-peptide (nmol/l)	0.9	0.38	0.3–2.3	1.0	0.41	0.4–2.0
ALT (ukat/l)	0.6	0.45	0.2–2.0	0.4	0.16	0.2–0.9
AST (ukat/l)	0.5	0.19	0.2–1.0	0.5	0.22	0.2–1.0

TRG – triacylglycerols, ALT – alanine aminotransferase, AST – aspartate aminotransferase

Tab. 3. Relation between IAT and selected anthropometrical parameters (age adjusted)

	Boys			Girls		
	r1	t	p	r1	t	p
BMI	0.44	2.89	0.006**	0.42	2.47	0.019*
chest	0.45	2.9	0.005***	0.42	2.51	0.018*
wais	0.65	5.07	0.0000***	0.46	2.77	0.009**
hips	0.34	2.13	0.03*	0.48	2.95	0.006**
waist /hips (WHR)	0.61	4.57	0.001***	0.21	1.18	0.24

BMI – body mass index, WHR – waist/hip ratio, IAT – intra-abdominal fat, *<0.05, **<0.01, ***<0.001

Tab. 4. Relation between intra-abdominal space and selected anthropometrical parameters (age adjusted)

	Boys			Girls		
	r1	t	p	r1	t	p
SF subscapular	0.44	2.94	0.005**	0.46	2.80	0.009**
SF chest II	0.55	3.92	0.004***	0.33	1.86	0.07
SF suprailiac	0.515	3.55	0.0011**	0.33	2.89	0.06
SF – abdomen	0.549	3.88	0.0004***	0.52	3.19	0.003**
sum of 10 SF	0.530	3.69	0.0007***	0.41	2.42	0.02

SF – skin fold, ** p<0.01, *** p<0.001

Tab. 5. Relation between IAT and selected metabolic parameters (age adjusted)

	Boys			Girls		
	r1	t	p	r1	t	p
insulin (mIU/l)	0.03	0.21	0.832	–0.89	0.44	0.83
C – peptide (nmol/l)	0.11	0.64	0.525	0.04	0.21	0.83
AST (ukat/l)	0.15	0.90	0.369	–0.24	1.27	0.21
ALT (ukat/l)	0.24	1.46	0.153	0.01	0.09	0.92
cholesterol (mmol/l)	0.04	0.24	0.80	0.03	0.15	0.87
triacylglycerols (mmol/l)	0.418	2.72	0.010*	0.20	1.08	0.28
uric acid (umol/l)	0.27	1.57	0.124	0.33	1.78	0.08

* p<0.05

that the correlation between obesity and high morbidity risk starts at an early age (5, 16). Compared to adults, the amount of visceral fat in children is relatively small, although it is difficult to compare absolute amounts due to the large differences in the body dimensions of children (16). Intra-abdominal fat can be demonstrated in children as young as five (8), although its amount is small. It is generally true that the amount of intra-abdominal fat increases with the higher degree of obesity (9, 17). The relation between the amount of visceral and total amount of adipose tissue is, however, more complex. In childhood, the variability of the amount of intra-abdominal fat is largely independent of the total amount of fat (8). Differences in sexual dimorphism in puberty in fat distribution are influenced by the different hormonal levels, by the number of receptors, capillary blood flow and enzyme activity, which enhance the synthesis or degradation of fats. Direct methods of detection of the amount of visceral fat are very accurate but not easily accessible in normal clinic practice; they are expensive and sometimes involve radiation emissions. At a younger school age the applicability of these methods is limited due to the inadequate degree of cooperation from the child. That is why a number of anthropometrical parameters are used in clinical practice and epidemiological studies; these, however, reflect the amount of visceral fat only indirectly. Ultrasound investigation of the intra-abdominal space is usually available; it does not require much time and does not involve radiation emissions. The disadvantage is its inaccuracy due to the presence of other structures within the measured space, the fuzzy borders of the measured structures and the compression of the abdominal wall by the probe (18). Nevertheless, a number of studies in adults have shown a significant correlation between ultrasound measurement and direct methods of measurement of visceral fat, and between ultrasound measurement and anthropometrical parameters that indicate fat distribution (11–14, 18). There are few studies on applying ultrasound measurement of the intra-abdominal space in children (14). We have demonstrated a significant relation between the intra-abdominal space and BMI as well as central skin folds. The more significant relations between anthropometrical parameters and the intra-abdominal space in boys than in girls is probably due to the larger total amount of fat in girls and to the initial different distribution of fat in girls at the time of puberty. Some authors have demonstrated a close correlation between the amount of visceral fat and hyperlipidemia and hyperinsulinemia, even in childhood (9, 16, 22, 23). The results of this study have not confirmed the correlation of hyperinsulinemia with the amount of visceral fat, which is in compliance with the conclusions of other authors (10, 13, 21). However, this may be due to the relatively smaller amount of visceral fat in children (9, 10) as well as to the inaccuracy of the direct methods applied. The fact that a positive correlation between higher triacylglycerol levels in the group of investigated boys was found, but not in the group of girls, was probably due to the higher accumulation of intra-abdominal fat in boys in puberty (21) and can serve as an early indicator of the later development of the metabolic syndrome.

CONCLUSION

Ultrasound measurement is a useful and available indirect method of measuring the amount of visceral fat in children. There is a significant correlation between ultrasound measurement and selected anthropometrical parameters, and this relation is statistically more significant in boys than in girls. Further longitudinal monitoring would be useful to verify the relation between IAT measured by ultrasound and metabolic parameters.

Abbreviations

BMI – body mass index
IAT – intra-abdominal fat measured on ultrasound
SD – standard deviation
WHR – waist/hip ratio

REFERENCES

1. **Rolland-Cachera, M.-F., Castetbon, K., Arnault, N. et al.:** Body mass index in 7 – 9-y-old French children: frequency of obesity, overweight and thinnes. Int. J. Obes., 2002, 26, pp. 1610-1616.
2. World Health Organization. Malnutrition worldwide. http://www.who.int/nut/malnutrition_worldwide.htm. Accessed, July 2000.
3. **Rosner, B. B., Prineas, R., Loggie, J., Daniels, S. R.:** Percentiles for body mass index in U.S. children 5 - 17 years of age. Journal of Pediatrics, 1998, 132, pp. 211-222.
4. **Nicklas, T. A., Webber, L. S., Srinivasan, S. R., Berenson, G. S.:** Secular trends in dietary intakes and cardiovascular risk factors of 10-y-old children: the Bogalusa Heart Survey (1973-1988). Am. J. Clin. Nutr., 1993, 57, pp. 930-937.
5. **Asayama, K., Ozeki, T., Sugihara, S. et al.:** Criteria for medical intervention in obese children: a new definition of "obesity disease" in Japanese children. Pediatr Int., 2003, 45, pp. 642-646.
6. **Dietz, W. H.:** Health consequences of obesity in youth: childhood predictors of adult disease. Pediatrics, 1998, 101, pp. 518-525.
7. **Goran, MI.** Measurement Issues Related to Surveys of Childhood Obesity: Assessment of Body Composition, Body Fat Distribution, Physical Activity, and Food Intake. Pediatrics, 1998, 101 (Suppl.).
8. **Goran, M. I.:** Visceral fat in prepubertal children: Influence of obesity, anthropometry, ethnicity, gender, diet and growth. Am. J. Human. Biol., 1999, 11, pp. 201-207.
9. **Brambilla, P., Manzoni, P., Agostini, G. et al.:** Persisting obesity starting before puberty is associated with stable intraabdominal fat during adolescence. Int. J. Obes., 1999, 23, pp. 299-303.
10. **Tershakovec, A. M., Kuppler, K. M., Zemel, B. S. et al.:** Body composition and metabolic factors in obese children and adolescents. Int. J. Obes., 2003, 27, pp. 19-24.
11. **Armellini, F., Zamboni, M., Rigo, L. et al.:** The contribution of Sonography to the Measurement of Intra-Abdominal Fat. J. Clin. Ultrasound, 1990, 18, pp. 563-567.
12. **Armellini, F., Zamboni, M., Robbi, R. et al.:** Total and intraabdominal fat measurements by ultrasound and computerized tomography. Int. J. Obes., 1993, 17, pp. 209-214.
13. **Tamura, A., Mori, T., Hara, Y., Komiyama, A.:** Preperitoneal fat thickeness in childhood obesity: association with serum insulin concentration. Pediatr. Int., 2000, 42, pp. 155-159.
14. **Ferrozzi, F., Zuccoli, G., Tognini, G. et al.:** An assessment of abdominal fatty tissue distribution in obese children. A comparison between echography and computed tomography. Radiol. Med., 1999, 98, pp. 490-494.
15. **Cole, T. J., Bellizzi, M. C., Flegal, K. M., Dietz, W. H.:** Establishing a standard definition for child overweight and obesity worldwide: international survey. BMJ, 2000, 320, pp. 1240-1246.
16. **Asayama, K., Dobashi, K., Hayashibe, H. et al.:** Threshold values of visceral fat measures and their anthropometric alternatives for metabolic derangement in Japanese obese boys. Int. J. Obes., 2002, 26, pp. 208-213.
17. **Brambilla, P., Manzoni, P., Sironi, S. et al.:** Peripheral and abdominal adiposity in childhood obesity. Int. J. Obes., 1994, 18, pp. 795-800.
18. **van der Kooy, K., Seidell, J. C.:** Techniques for the measurement of visceral fat: a practical guide. Int. J. Obes. (1993), 17, pp. 187-196
19. **Gower, B.A., Nagy, T.R., Goran, M.I.:** Visceral Fat, Insulin Sensitivity, and Lipids in Prepubertal Children. Diabetes, 1999, 48, pp. 1115-1521.
20. **Owens, S., Gutin, B., Barbeau, P. et al.:** Visceral adipose tissue and markers of the insulin resistance syndrome in obese black and white teenagers. Obes. Res., 2000, 8, pp. 287-293.
21. **Goran, M. I., Bergman, R. N., Gower, B. A.:** Influence of total vs. visceral fat on insulin action and secretion in African American and white children. Obes. Res., 2001, 9, pp. 423-431.

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