Metabolic consequences of childhood obesity—a preliminary report

KSH de Silva[1], VP Wickramasinghe[1] and **INA Gooneratne[2]**

(Index words: Metabolic syndrome, non-alcoholic steatohepatitis, obese Sri Lankan children, waist circumference)

Abstract

Introduction Childhood obesity is increasing in Sri Lanka. Obesity related morbidity is mainly associated with the metabolic syndrome (MetS) and non-alcoholic steatohepatitis (NASH). Recent studies have shown these serious health consequences in obese children.

Objectives The objectives of our study were to document the presence of MetS and NASH in obese Sri Lankan children, to correlate the fat mass (FM) with the waist circumference (WC) and the body mass index (BMI), and to compare the association of the WC, BMI and the WHR (waist-hip ratio) with the metabolic derangements.

Method Children attending the Obesity Clinic at Lady Ridgeway Hospital, Colombo, from November 2004 to September 2005 were studied. The relevant socio-demographic data, anthropometric measurements and examination findings were documented. After a 12-hour overnight fast, blood was taken for estimation of lipid profile, serum insulin, liver enzymes and blood glucose. The oral glucose tolerance test (OGTT) was done in children over 5 years of age. Fatty infiltration of the liver was assessed by identifying specific features on ultrasonography and the degree of infiltration was given a score. We modified the International Diabetes Federation (IDF) 2004 guidelines to define MetS. NASH was defined as fatty infiltration of the liver associated with a raised serum ALT.

Results Seventy children (40 boys) were studied. The mean (SD) age was 9.7 (2.5) and 9.3 (3.0) years for boys and girls respectively. Mean BMI was 25.9 in both groups. All patients had a WC > 98th percentile. MetS was found in 13 of the 63 (21%) children on whom all criteria were assessed. Sixty children had ultrasonography and NASH was seen in 11 (18%). The correlation of the percentage FM was greater with the BMI ($r = 0.80$; $p < 0.001$) than with the WC ($r = 0.56$; $p < 0.001$), but the WC was more

[1]*Senior Lecturer, Department of Paediatrics, Faculty of Medicine, Colombo, and* [2]*Radiologist, Lady Ridgeway Hospital, Colombo.*

Correspondence: KSH de S, *e-mail <shamyadesilva@hotmail.com>* *(Competing interests: none declared). Received 27 June 2006 and revised version accepted 20 August 2006.*

significantly associated with the metabolic derangements than either BMI or WHR.

Conclusions Serious metabolic abnormalities are found in obese Sri Lankan children and the WC is a reliable indicator of these derangements.

Introduction

The widespread incidence of childhood obesity is reflected in numerous reports from several countries spanning all continents [1,2]. Apart from its psychosocial implications, obesity related morbidity is mainly associated with the metabolic syndrome (MetS) and non-alcoholic steatohepatitis (NASH). Although deemed to occur in adults, several countries have reported these conditions in children and adolescents [2,3]. But the metabolic consequences associated with childhood obesity have not been previously reported in Sri Lanka.

Objectives

The objectives of this study were to document the presence of MetS and NASH in obese Sri Lankan children, identify the association of fat mass (FM) with obesity indicators (WC and BMI) and to identify the anthropometric measure which best predicts the metabolic derangements.

Method

Children over 2 years of age referred to the Obesity Clinic of the Lady Ridgeway Hospital, Colombo from November 2004 to September 2005 were recruited after explaining the study to the parents and older children. The Ethical Review Committee of the Faculty of Medicine, Colombo approved the study.

Socio-demographic data were obtained using an interviewer administered questionnaire. Each child was examined and the findings were recorded. Blood was taken after a 12-hour overnight fast for blood glucose, serum insulin, lipid profile, serum ALT and AST. The OGTT was performed in children over 5 years of age after administration of 1.75 g of glucose/kg to a maximum of 75 g [2].

Weight, height, hip circumference (HC) and WC were measured and the BMI (kg/m^2) and WHR were calculated. The weights and heights of the patients were measured according to standard practice using an electronic weighing scale and a wall mounted stadiometer. The WC, which is an indicator of central obesity, was measured in the horizontal plane midway between the costal margin and the iliac crest in the mid-axillary line [4]. The HC was measured at the maximum extension of the buttocks [5].

Obesity associated morbidity and mortality are related to the fat content of the body. It is reported that Sri Lankan children have a higher percentage of fat that could be associated with adverse health outcomes, which is not detected by currently available BMI cut-off values [6]. Hence we calculated the fat mass (FM) of the children.

The fat free mass (FFM) was assessed initially using tetra-polar bio-electrical impedance analysis (BIA), based on the equation described previously which gives the best prediction of FFM in Sri Lankan children [7]. The absolute FM was calculated by subtracting the FFM from the weight, based on the two-compartment body composition model that identifies the body as being composed of two components, the FM and FFM [7]. Percentage fat mass (%FM) refers to the absolute fat mass expressed as a fraction of the body weight.

Fatty infiltration of the liver was assessed using ultrasonography by a single investigator (INAG) and graded according to ultrasonic appearance of three features: liver echo texture; liver-diaphragm differentiation in echo amplitude with the hepatic echo penetration and clarity of liver blood vessels. Each feature was given a score of 0–3 and the overall score was taken to define the degree of fatty liver change. A score of 1–3 was indicative of mild fatty liver change, 4–6 was moderate, and 7–9 denoted severe infiltration [8].

Definitions used in the study

Obesity was defined as a BMI $\geq 95^{th}$ percentile for age and gender—NCHS/CDC 2000 growth charts [9].

We used a modification to the International Diabetes Federation (IDF) 2004 guidelines [4] to define MetS as a waist circumference $> 98^{th}$ percentile–UK growth charts 2004, with 2 of the following criteria: serum triglyceride $> 95^{th}$ percentile, HDL cholesterol $< 5^{th}$ percentile for age and gender [10], hypertension, and abnormal glucose homeostasis.

Hypertension was defined as an average systolic or diastolic blood pressure (SBP, DBP) $\geq 95^{th}$ percentile for age and gender [11].

Abnormal glucose homeostasis was inferred if either insulin resistance or impaired glucose tolerance (IGT) was present. Insulin resistance was expressed as HOMA-IR (homeostasis model assessment-insulin resistance) calculated using the following formula—fasting insulin ($\mu U/ml$) × fasting blood glucose (mmol/l) ÷ 22.5 [2,12]. HOMA-IR value $> 75^{th}$ percentile (4^{th} quartile value) for the series was considered as being indicative of insulin resistance [13].

IGT was defined as a fasting blood glucose ≥ 100 mg/dl (5.6 mmol/l) but < 126 mg/dl (7.0 mmol/l) or 2-hour OGTT blood glucose ≥ 140 mg/dl (7.8 mmol/l) but < 200 mg/dl (11.1 mmol/l) or the presence of overt diabetes mellitus [14].

Non-alcoholic steatohepatitis (NASH) was defined as a combination of ultrasound evidence of fatty infiltration of the liver associated with a raised ALT [8].

Results

Of the 92 children seen in the clinic during the study period, 70 (76%) consented to participate in the study. The

demographic features of the study population are given in Table 1. The age of the patients ranged from 25 to 177 months. The %FM (SD) of 47.5 (5.7) in boys and 48.6 (10.9) in girls was far in excess of the values associated with adverse health outcomes (>25% in boys and >32% in girls [15]).

Disturbing trends were noted in the blood pressures as shown in Table 2. The mean (SD) HOMA-IR value was 2.08 (1.8) whereas the value indicating insulin resistance (4th quartile value) for this study population was >2.51. Table 3 gives the manifestations of abnormal glucose homeostasis. Sixteen children had insulin resistance, and 3 had Type 2 diabetes mellitus (T2DM). The different components of the MetS observed are given in Table 4. All children had a WC >98th percentile. Thirteen children (21%) had MetS out of the 63 in whom all criteria were assessed. Sixty had ultrasonography of whom 11 (18%) had evidence of NASH (Table 5).

When evaluating the association of FM with indicators of obesity, we found that the correlation of the %FM was greater with the BMI (r=0.80; p<0.001) than with the WC (r=0.56; p<0.001). We then looked at the relationship of the WC, BMI and WHR with the different components of the MetS (Table 6). WC showed a statistically significant association with the metabolic derangements, and both SBP and DBP were significantly associated with all 3 indicators of obesity.

Table 1. **Demographic features of the study population**

	Boys mean (SD)	*Girls mean (SD)*
Number	40	30
Age (years)	9.7 (2.5)	9.3 (3.0)
BMI (kg/m²)	25.9 (3.6)	25.9 (4.4)
WC	84.2 (11.4)	84.0 (12.0)
HC	85.7 (10.9)	90.1 (12.2)
WHR	0.98 (0.05)	0.93 (0.05)
FM (kg)	24.2 (10.1)	26.7 (10.9)
%FM	47.5 (5.7)	48.6 (10.9)

Table 2. **Blood pressure pattern of the study population (*n*=70)**

Blood pressure	*Boys*	*Girls*	*(%)*
High normal BP*			
SBP	2	2	6
DBP	1	4	7
Hypertension			
SBP	5	3	11
DBP	0	3	4

*Average systolic or diastolic BP ≥ 90th and <95th percentile for age and gender
SBP=systolic blood pressure, and DPB=diastolic blood pressure

Table 3. **Profile of abnormal glucose homeostasis of the study population**

	Boys	*Girls*	*(%)*
HOMA-IR *n*=63 (Q4>2.51)	9	7	25
FBS *n*=63 (≥100 mg/dl)	0	3	5
OGTT *n*=47 (2 hr≥140 mg/dl)	1	3	9
T2DM	1	2	
Abnormal glucose homeostasis *n*=63	9	8	27

Table 4. **Components of the metabolic syndrome in the study population**

	Boys	*Girls*	*(%)*
WC (>98th percentile)	40	30	100
TG *n*=70 (>95th percentile)	18	9	39
HDL *n*=70 (<5th percentile)	1	1	3
HBP *n*=70 (≥95th percentile)			
SBP	5	3	11
DBP	0	3	4
Abnormal glucose homeostasis *n*=63	9	8	27
Metabolic syndrome *n*=63	5	8	21

Table 5. **Liver involvement in the study population (*n*=60)**

	Boys	*Girls*	*(%)*
Liver score			
1–3	18	12	50
4–6	—	—	—
7–9	—	—	—
ALT (>40 iu/l)*	12	3	25
NASH	9	2	18

*Upper limit of normal for the reference laboratory

Table 6. **Association of obesity indicators with metabolic derangements**

	TG	*SBP*	*DBP*	*HOMA-IR*
WC	r=0.24 p=0.04	r=0.58 p<0.001	r=0.48 p<0.001	r=0.32 p=0.01
BMI	r=0.22 p=0.07	r=0.41 p<0.001	r=0.28 p=0.02	r=0.21 p=0.09
WHR	r=0.1 p=0.43	r=0.28 p=0.02	r=0.25 p=0.03	r=–0.09 p=0.49

Discussion

Recent evidence from affluent countries of the world has shown that the metabolic derangements associated with obesity are prevalent among obese children and increases with worsening obesity [2]. Under nutrition was the main form of malnutrition seen in Sri Lanka in the past. But recently due to various factors, obesity as a form of malnutrition is becoming increasingly prevalent.

Although MetS has been defined in adults [4] there is no definition of the syndrome described in children. Therefore we used a modification to the IDF 2004 guidelines [4] to define childhood MetS. A significant HOMA-IR indicating insulin resistance was seen in 16 out of 63 (25%) children. Acanthosis nigricans, which is an early manifestation of insulin resistance, was seen in 58 (82.9%). We believe this would be a useful clinical sign for early detection of insulin resistance to initiate appropriate intervention in obese children.

Abdominal obesity is the form of obesity most strongly associated with the MetS and has a more significant correlation with the individual components of the syndrome than an increased BMI [16]. In our study, the association of the WHR with the metabolic derangements was not significant whereas the WC, which can be easily measured in a child, showed a significant association with increased triglyceride levels, hypertension and insulin resistance (Table 6). According to the modified IDF definition we identified MetS in 21% of children in our study. Higher rates have been reported from more affluent countries where approximately one third of obese children have been reported as having MetS [2,3].

Fatty infiltration of the liver encompasses a spectrum of disorders [17]. Initially, non-alcoholic fatty liver disease (NAFLD) is the stage when fatty infiltration of the liver exceeds 5–10% by weight. This progresses to fatty liver or hepatic steatosis without liver injury, which in turn leads to NASH ultimately resulting in cirrhosis. We did not perform liver biopsies on our patients. In the absence of a biopsy, which is the gold standard for demonstrating fatty infiltration, we used ultrasonography which has been shown to correlate well with histological evidence of fatty infiltration, to document the degree of liver involvement [8]. Hepatic steatosis was seen in 50% and NASH in 18% of our children which is much less than the 77% and 24% respectively reported from China [8].

Although less than from regional and western countries, the finding of MetS in 21% and NASH in 18% of young obese children is very disturbing. Seeds of adult illness are sown in childhood and childhood illnesses track in to adulthood [2,3]. Insulin resistance and the metabolic derangements will reverse with proper dietary management and life style modifications. Therefore, unless adequate measures are taken urgently to address the problem of obesity in children, cardiovascular disease and type 2 diabetes mellitus occurring as complications of MetS [2,16], will be diseases of the adolescent and young adult in the not too distant future in Sri Lanka.

Conclusions

In this preliminary study we have found that serious metabolic consequences of obesity are seen in Sri Lankan children. The presence of acanthosis nigricans is a useful early indicator of insulin resistance. The WC is a more reliable indicator than the BMI, of markers of metabolic derangements that were evaluated in this study.

We believe that the WC and presence of acanthosis nigricans could be effectively used for screening overweight and obese children for early identification of potentially serious metabolic abnormalities.

Acknowledgments

We thank Prof SP Lamabadusuriya and Dr R Ajanthan for helping in the recruitment of children for the study.

References

1. Lobstein T, Baur L, Uauy R. Obesity in children and young people: a crisis in public health. *Obesity Reviews* 2004; **5**:(Suppl.1), 4–85.
2. Weiss R, Dziura J, Burgert TS, Tamborlane WV, Taksali SE, et al. Obesity and the Metabolic Syndrome in Children and Adolescents. *New England Journal of Medicine* 2004; **350**: 2362–74.
3. De Ferranti SD, Gauvreau K, Ludwig DS, Neufeld EJ, Newburger JW, et al. Prevalence of the Metabolic Syndrome in American Adolescents. Findings from the Third National Health and Nutrition Examination Survey. *Circulation* 2004; **110**: 2494–97.
4. Alberti KGMM, Zimmet P, Shaw J. Metabolic syndrome-a new world-wide definition. A consensus statement from the International Diabetes federation. *Diabetic Medicine* 2006; **23**: 469–80.
5. Callaway CW, Chumlea WC, Bouchard C, Himes JH, Lohman TG, et al. Circumferences: In: Lohman TG, Roche AF, Martorella R, ed. *Anthropometric Standardization Reference Manual*. Human Kinetics, Champaign, IL 1985; 39–54.
6. Wickramasinghe VP, Cleghorn GJ, Edmiston KA, Murphy AJ, Abbott RA, et al. Validity of BMI as a measure of obesity in Australian white Caucasian and Australian Sri Lankan children. *Annals of Human Biology* 2005; **32**: 60–72.
7. Wickramasinghe VP, Cleghorn GJ, Edmiston KA, Murphy AJ, Abbott RA, et al. Ability of bioelectrical impedance to predict percentage fat mass in children of two different ethnic origins. *International Journal of Body Composition Research* 2005; **3**: 15–24.
8. Chan DFY, Li AM, Chu WCW, Chan MHM, Wong EMC, et al. Hepatic steatosis in obese Chinese children. *International Journal of Obesity* 2004; **28**: 1257–63.
9. Barlow SE, Dietz WH. Obesity evaluation and treatment: Expert Committee recommendations. *Pediatrics*. 1998; **102**: E29. Accessed on 13th January 2002. www.pediatrics.aappublications.org/cgi/content/full/102/3/e29.

10. National Cholesterol Education Program (NCEP). Report of Expert Panel on Blood Cholesterol Levels in Children and Adolescents. *Pediatrics* 1992; **89**:525–84.

11. Update on the 1987 Task Force report on high blood pressure in children and adolescents: A working group report from the National High Blood Pressure Education Program. *Pediatrics* 1996; **98**: 649–58.

12. Matthews DR, Hosker JP, Rudenski AS, Naylor BA, Treacher DF, et al. Homeostasis model assessment: insulin resistance and β-cell function from fasting plasma glucose and insulin concentrations in man. *Diabetologia* 1985; **28**: 412–9.

13. Ascaso JF, Pardo S, Real JT, Lorente RI, Priego A, et al. Diagnosing insulin resistance by simple quantitative methods in subjects with normal glucose metabolism. *Diabetes Care* 2003; **26**: 3320–25.

14. American Diabetes Association—Position Statement. Diagnosis and Classification of Diabetes Mellitus. *Diabetes Care* 2005; **28**:(Suppl.1), S37–S42.

15. Lohman TG. The prevalence of obesity in children in the United States. In: Advances in body composition assessment. Champaign, IL. Human Kinetics 1992; Monograph **3**: 79–89.

16. Grundy SM, Brewer Jr. B, Cleeman MD, Smith Jr. SC, Lenfant MD. Definition of Metabolic Syndrome. Report of the National Heart, Lung and Blood Institute/ American Heart Association Conference on Scientific Issues Related to Definition. *Circulation* 2004; **109**: 433–38.

17. Salt WB. Nonalcoholic fatty liver disease (NAFLD): a comprehensive review. *Journal of Insurance Medicine* 2004; **36**: 27–41.

Effects of the medical liability system in Australia, the UK, and the USA

In the USA, medical professional liability insurance premiums skyrocketed after 2000, with annual increases in several states of 30% or over. By 2001, yearly rates for obstetricians in Florida ranged from US $ 143 000 to US $ 203 000. Although the overall level of tort costs in the UK is less than in the USA and Australia, trends in the UK National Health System's expenditure for clinical negligence have been similar, growing from UK £ 242 million in 1998-99 (2002 £) to UK £ 446 million in 2001-02 (up-to-date data for England alone is available from the National Health System Litigation Authority). In response, the governments of all three countries have commissioned or undertaken studies of the dilemma.

Kessler DP, Summerton N, Graham JR. Effects of the medical liability system in Australia, the UK and the USA. *The Lancet* 2006; **368**: 240-6