University of Jaffna

Dr.Arunasalam Sivapathasundaram
Memorial Lecture - 2016

Childhood Obesity : The Silent Epidemic

by

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MBBS,MD(Paed),DCH,Ph.D
Professor in Paediatrics
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on

Friday 19th February 2016

at

Kailasapathy Auditorum
University of Jaffna

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Manuscript for DR. SIVAPATHASUNDARAM MEMORIAL LECTURE 2016

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Dr. Arunasalam Sivapathasundaram was born on 23rd November 1939 at Puloly, PointPedro to Somasundarampillai Arunasalam and Valliammai, in a family of six. Born to a school teacher father, he was named after his grand uncle, late Mr. S. Sivapathasundaram, who had been a school principal. Coming from an academic background, Dr. Sivapathasundaram went on to pursue higher studies as much as his siblings did in their respective fields.

Dr. Sivapathasundaram had his primary education at Vadamaradchi Hindu Girls' College and Secondary Education at Hartly College Jaffna. Apart from excelling in studies he excelled in speech and drama securing prices. His skills in drama did not confine to school premises but was portrayed on Radio Ceylon with Dr. Sivathamby and inspired the Jaffna Hospital Staff Welfare Society to produce drama, where he played the main role.

He obtained his MBBS from University of Ceylon in 1963. He obtained the Diploma in Child Health (Sri Lanka) in 1970, proceeded to London afterwards and obtained the Diploma in Child Health (London) in 1975 and the membership of the Royal College of Physicians in 1977. During his career, he served in many parts of the country including Lady Ridgeway Hospital for Children Colombo before assuming duties as

Consultant Paediatrician at Base Hospital Point Pedro in 1974. After serving in Point Pedro, he was appointed as Consultant Paediatrician to the Teaching General Hospital, Jaffna in February 1983. He was an active member of the Jaffna Medical Association and in 1987 became the secretary before his untimely death in the very same year.

Although it was before my era, I have heard that when he worked as a Paediatrician, he was punctual, disciplined, meticulous, kind and was very detailed in the treatment of his patients. He had been a skilled clinician with compassion towards his patients where he followed them to the very end. He used to visit his referred patients in other units as much as even to the operation theater to find out the outcome. He loved children very much. His dealings with Colleagues, junior doctors, medical students and other ward staff were very cordial, but if the appropriate had not happened he would never hesitate to put things right for the betterment of the patients and the system. All patients were equal to him. As much as of the betterment of the patients, he took a keen interest in the welfare of the hospital and its staff. He was able to come up with meaningful and practical solution and suggestions for the improvement. He always stood up against injustice and unfairness.

He took a great interest in the activities of the Jaffna Medical Association, often taking part in the clinical demonstrations and discussions. One could often discern his ample knowledge and clarity of thought, he had. This was a great boon for the students who clerked under him.

As an individual, he was a highly religious person. He was highly principled, honest and sincere person, never afraid to express his opinion. He was energetic and always ready to fight for a cause. He was always ready to help anyone in distress or need.

He was married to Mrs. Mangaleshwary who come from a similar background. She had been an inspiration to his work and well supported her husband. They were blessed with 4 daughters. As much as he did to the community, Dr. Sivapathasundaram cared for his family and discharged his family responsibilities to their entire satisfaction.

Although he is not in my living memories I have made to understand that Dr. Arunasalam Sivapathasundaram had been a great son of mother Sri Lanka where his great legacy would be remembers by all of us at present and in years to come.

Ladies and Gentlemen, I am honored to be selected to pay tribute to this great personality Dr. Arunasalam Sivapathasundaram, who was always interested in the wellbeing of children. Being a paediatrician, and having similar interest to society, it is a rare opportunity one gets to pay tribute to such a great personality, and today I have been fortunate to deliver this talk where I dedicate my lecture today on "Childhood Obesity: The Silent Epidemic" to this great son of mother Sri Lanka.

Background

Obesity the new form of malnutrition is spreading in epidemic proportions all over the world. Whilst it is on the rise even in regions where under nutrition is not adequately controlled, it is fast penetrating the paediatric populations. Nearly five percent of 5-17 year old children living in the Asia-Pacific region are found to be either overweight or obese (Lobstein *et al* 2004). Childhood obesity is also increasing in Sri Lanka as shown by 14–15% prevalence of overweight and obesity among 8-12 year old school children in the district of Colombo (Wickramasighe *et al,* 2004).

Obesity is a major risk factor for many non-communicable diseases (NCD) such as diabetes, hypertension, dyslipidaemia and some forms of cancer. The pathophysiology is driven by the excess fat content seen amongst the obese (WHO, 2000). Therefore, direct measurements of fat content would be helpful in obesity management programmes as well as in reducing the incidence of NCD.

The amount of body fat associated with morbidity in children is not clearly understood. Few studies carried out in the UK, USA and Australia have attempted to establish the level of percentage body fat that would be associated with NCD risk among children (Dwyer and Blizzard, 1996; Lohman, 1992; Williams *et al.*, 1992). Although a percentage fat mass (FM) of 20-25 % in boys and 25-32% in girls was considered desirable cutoff for NCD prevention among these populations, the authors cautioned that such cut off values could be influenced by factors such as genetics and geography between and within populations.

Health Consequences of Obesity: Metabolic Syndrome

Obesity related morbidity is mainly associated with insulin resistance which leads to "metabolic syndrome". Metabolic syndrome (MetS) was identified as early as 1923 as clustering of hypertension, obesity and gout by Kylin. In 1940's Vague noted that male type or android type fat distribution was associated with metabolic derangements seen in diabetes mellitus and CVD (Alberti *et al.*, 2006).

In 1988, during the Banting lecture, Gerald Reaven renewed the concept of syndrome X as the clustering of a group of cardiovascular risk factors. They were identified as hypertension, obesity, high triglyceride (TG) and low HDL. The syndrome had been given several names such as insulin resistance syndrome, cardiovascular metabolic syndrome and

deadly quartet (Albert *et al.*, 2006). As this was an illness that began to emerge in the 1990's, the need for a unified definition was obvious. In 1998 WHO proposed a definition named as metabolic syndrome rather than insulin resistance syndrome in the absence of definitive evidence to suggest insulin resistance being behind the pathophysiology of all components of this illness (Alberti *et al.*, 1998). It was seen that most individuals who developed cardio vascular disease (CVD) and type 2 diabetes mellitus (T2DM) have multiple risk factors. There are six main components identified related to this (Grundy *et al.*, 2004). They are;

1. abdominal obesity mainly abdominal fat deposits
2. insulin resistance with or without impaired glucose metabolism
3. atherogenic dyslipidaemia,
4. pro-inflammatory state (denoted by elevated C-reactive protein),
5. prothrombotic state (denoted by elevated anti thrombin III levels)
6. Hypertension.

They are also susceptible to polycystic ovary syndrome, fatty liver, cholesterol gall stones, bronchial asthma, sleep disorders and some malignant tumours.

Since identifying the components of MetS, attempts have been made to develop a definition to identify MetS. Most accepted definitions were proposed by; WHO (1999), The European Group for the Study of Insulin Resistance (EGIR) (Balkan *et al.*, 1999) and the National Cholesterol Education Programme, Third Adult Treatment Panel (NCEP ATP III, 2001). All these definitions included the common components of MetS. They are obesity, insulin resistance, dyslipidaemia and hypertension. But some of the assessment criteria used were not practical to measure in day to day clinical settings and cutoff points used to define each were different and led to confusion.

The prevalence of MetS varied depending on the cutoff value used. Dunstan *et al.* (2002) studied the prevalence of MetS in Australian adults using each of the above three definitions. The prevalence of MetS varied from 15.8% to 20.7% depending on the definition used. Only 9.2% was defined by all three methods. However, whatever the diagnostic tool that was used, it is clear that the incidence of MetS is rising making it an emerging health problem after controlling infectious diseases in the world. Therefore a simpler, practical definition that could be used in any part of the world to identify patients at risk of developing CVD and T2DM was needed. The International Diabetic Federation (IDF) proposed a world-wide definition to identify MetS in adults (Alberti, *et al.* 2006). It considered central obesity measured by Waist circumference (WC), raised TG, reduced HDL, hypertension and raised fasting blood glucose as diagnostic criteria.

MetS is not an entity that is confined to adults. Studies have shown that it is prevalent among obese children and increases with worsening obesity (Weiss, *et al.*, 2004). A study from the United States showed that 20% of obese children and adolescents had two or more metabolic derangements; raised insulin, dyslipidaemia or hypertension (Freedman, *et al.*, 2001). Viner *et al.* (2005) showed that 33% of multi-ethnic British children had three or more risk factors (obesity, abnormal glucose homeostasis, dyslipidaemia and hypertension) and a further 33% had one metabolic derangement associated with obesity.

IDF published a new set of diagnostic criteria to be used in children (Zimmet *et al*, 2007). However, the recommendation is to use them on 10 - 16 year old children and use the adult guidelines for children above 16 years. Children under 10 are required to be screened for metabolic derangements if they have risk factors such as obesity but not to

diagnose MetS as evidence is lacking. However, the present IDF cutoff values may not be realistic as they have suggested applying uniformed cutoff values. Use of uniform cutoff values will lower the sensitivity as normal values in a childhood population depends on the age and sex of the children. Based on IDF guidelines, but instead of using the IDF cutoff values, De Silva *et al.*, (2006) used age and sex specific cutoff values to define MetS showed the prevalence to be 21% among obese Sri Lankan children. In this study several criteria were used to define abnormal glucose homeostasis as single criteria is not powerful enough. There is evidence even in adults that fasting blood glucose itself does not diagnose many with IGT (Anand *et al.*, 2003) especially of different ethnic groups.

Viner *et al.* showed in a group of British children that 12% of the group had dysglycaemia based on OGTT while it would have detected a mere 1% on fasting blood glucose. OGTT and fasting insulin both together detected 45% to have abnormal glucose homeostasis. Therefore they considered that blood glucose either fasting or during OGTT is not sufficient to detect abnormal glucose homeostasis but need both glucose and insulin measurements (Viner *et al.*, 2005). It is prudent to use an insulin measure as it would be the earliest biochemical change associated with dysglycaemia/insulin resistance. Keskin *et al.* (2005) showed that HOMA-IR is more reliable than fasting glucose / insulin ratio (FGIR) and quantitative insulin sensitivity check index (QUICKI) in detecting insulin resistance in children and adolescents. HOMA-IR cutoff value of 3.16 was suggested (adult cutoff value suggested is 2.5).

Although, increased BMI had a higher risk for the development of T2DM and CVD, increased WC independently had a higher risk for the development of T2DM and CVD (Rexrode, 1998). WC reflects abdominal obesity and it varies with ethnicity. Therefore, there is a need to have

ethnic specific cutoff values (Tan, *et al.*, 2003). Insulin resistance is shown to have a clear association with risk of CVD in non-diabetic adults (Ruige, *et al.*, 1998). Elevated blood pressure is seen with insulin resistance and the association between the two differ from population to population (Alberti, *et al.*, 2006).

Pathogenesis of MetS is not fully understood. Insulin resistance and abdominal fat distribution are the two main factors that are being attributed to the pathogenesis of this illness (Anderson, *et al.*, 2001). Factors such as genetic makeup, physical activity, aging, proinflammatory state and hormonal deregulations are contributory factors (Alberti, *et al.*, 2006). It is suggested that the role of these causal factors may vary depending on ethnic groups (Saad, *et al.*, 1991; Anderson, *et al.*, 2001). Abdominal fat (visceral fat), especially excess omental fat is known to relate to components of MetS. It is shown that an increase of abdominal fat, even in the presence of normal BMI is associated with MetS (Carr *et al.*, 2004). The adiposity risk associated with MetS is correlated with intra-abdominal/visceral fat (Liu *et al.*, 2003). A practical way of getting an accurate measure of intra-abdominal fat is by sonography (Liu *et al.*, 2003; Chan *et al.*, 2004). Visceral fat is considered to be a significant factor that is associated in the pathogenesis of MetS. Mesenteric fat is considered more sensitive for lipolytic effects of catecholamine (Bjorntorp, 1990). MRI had been used to quantify the abdominal fat. However, its high cost and restricted availability limits its use in clinical practice.

South Asian populations are at a higher risk to develop metabolic derangements at a younger age (Whincup *et al,* 2002). Children of South Asian populations tend to accumulated more fat in the abdominal region when they put on weight probably contributed by their high fat and

carbohydrate diet and genetic predisposition compared to Caucasian children. Obesity related morbidity could affect any system of the body and also lead to many psychological problems (Ebbeling *et al.*, 2002).

Diagnosis of obesity

Obesity is defined as having excess body fat associated with adverse health outcomes. Therefore to diagnose obesity ideal method would be to measure the fat content of the body. Measuring one's fat mass is not straight forward in day to day clinical or epidemiological practice and therefore BMI is widely used as proxy measure of body fat content thus using as the diagnostic tool for obesity. The major limitation in using BMI as a marker of fat content is its low sensitivity in distinguishing fat mass from non-fat mass. Furthermore, the current BMI cutoff values are not based on biological disease risk but on population distribution of BMI parameter and thus not reflecting the risk associated with NCDs. In contrast, evidence suggests that other markers of body fat stores such as skin-fold thicknesses correlate better with elevated blood pressure (Aritinuno, 1984) and abnormal lipid profiles (Voors *et al.*, 1982), but it is not an easy method to use regularly especially in obese individuals It is further suggested that truncal fat pattern independent of its total body fat is related to lipid derangements of the body (Freedman *et al.*, 1989) and thus value WC as a marker of NCD morbidity is much higher.

Probable mechanisms of origin of NCDs

Malnutrition and its consequences in postnatal life and at a specific point in time is always discussed, but hardly ever prenatal malnutrition and its impact on health had been evaluated. Epidemiological studies have shown that early nutrition has long term effects. Based on retrospective observational epidemiological studies, Barker noted that nutritional status of early life determined the occurrence of many adult

diseases (Barker, 1994). He noted that small for date individuals are the most disadvantageous. His observations were not confined to cardio vascular diseases but also included diabetes, chronic bronchitis and acute appendicitis. These observations lead to look at the human being's life from conception till death as one continuum with few identifiable specific events in its course. Different impacts at different points on this journey have been discovered to give diverse outcomes with lasting effects. Since then the quest began to identify the exact effect/s responsible for different adverse health outcomes later in life.

Prenatal under-nutrition or under-nutrition during infancy was noted to have many adverse outcomes later in life with respect to blood pressure, cardiovascular mortality, impaired glucose homeostasis, abnormal lipid metabolism etc. This marked the beginning of "fetal origin of adult diseases" hypothesis on many non-communicable diseases. However, the outcomes later in life could have been influenced more by changes in the environment. An individual who was "programmed" to take a specific course in growth and development could be changed by environmental factors. Adverse health outcomes later in life were noted with over feeding as opposed to under nutrition in infancy. These lead Athul Singhal and Alan Lucas to propose the "accelerated post-natal growth" hypothesis (Singhal *et al*, 2004b).

Birth data from people in Hertfordshire born during 1911-1930 showed that death rates from coronary heart disease fell two-fold between those at the lower and upper ends of the birth weight distribution in favour of higher birth weights (Osmond *et al*, 1993). Study in Sheffield, England showed that term low birth weight infants were at a higher risk of developing cardiovascular diseases (Barker *et al*, 1993). A South Indian study showed similar results (Stein *et al*, 1996). Among men and women

aged 45 y and over, the prevalence of the disease fell from 18% in those who had a birth weight equal or less than 2.5kg to 4% in those who weighed 3.2kg or more. Therefore it was postulated that low rates of growth during antenatal period (depicted by low birth weight) was linked to the development of coronary heart disease later in adult life. This focused on intrauterine life, lead to a new era of research on "fetal origin of adult disease".

Hales and co workers studied a group of 59-70 year old men from Hertfordshire, UK. Ninetythree men out of 370 investigated had either impaired glucose tolerance (66) or newly diagnosed diabetes mellitus (27) (Hales *et al*, 1991). When stratified according to birth weight, the proportion of men with impaired glucose tolerance was 30% among those with a birth wieght of 2.5kg or less and fell to 14% when the birth weight 4.3kg or more. As adults, this same group (with low birth weight) of men had a higher BMI, Waist to hip ratio, systolic and diastolic blood pressures. The authors of this study concluded that reduced growth in early life (birth or at one year of age) is strongly linked to impaired glucose homeostasis.

However, there was another observation that could be made in this study (Hales *et al*, 1991). The plasma glucose concentration at 2 hours after a glucose load was highest in the men who had the lower weight at one year but higher BMI as adults (7.7 mmol/L) compared to those with a lower weight at one year and lower BMI as adults (6.6 mmol/l) and the lowest 2 hour glucose value was seen in those who had the higher birth weight and lower BMI as adults (5.8mmol/L). This denotes that not only weight at one year of life, but also later growth in combination is a better predictor of adverse health outcomes later in life.

Data from 1970 British birth cohort showed an inverse relationship between systolic blood pressure at 10 years of age and birth weight (Barker *et al*, 1989). When the cohort was stratified according to tertiles of birth weight and weight at 10 years of age, the highest mean systolic blood pressure was observed among those who were in the lowest birth weight and highest present weight tertile category and the lowest mean systolic blood pressure was seen in the group with highest birth weight and lowest present weight tertile category. The same cohort at 36 years of age also had a similar distribution of blood pressure. This once again shows that not only birth weight (and/or intrauterine environment) but also later growth in combination more effectively predicts adverse health outcomes later in life.

Barker thought that these were due to people being exposed to an adverse environment in utero resulting in failure to grow and continue to be exposed to an adverse environment in childhood and adult life, where this adverse environment in later life produced the effects attributed to programming in-utero. However results of some studies did not provide adequate evidence (Lithell *et al*, 1996).

A study done in India, which has a higher incidence of low birth weight rate, involving 16 to 19 year old children did not show significant association between birth weight and metabolic derangement during late adolescence (Krishnaswamy *et al*, 2002). But a higher odds ratio for coronary heart disease risk factors and diabetes was seen in those who had a low birth weight and were better nourished at time of study than those with low birth weight and under nourished at time of study.

If Barkers hypothesis was applicable then most of these diseases should have had a higher prevalence in disadvantageous countries in Asia

and African continents for a long period of time. But as we see today despite improvement in birth weight in many Asian countries, there is a rise in incidence of these non-communicable diseases (eg China, India). The change we observe in many of these countries today is a nutritional transition from a conservative Asian diet to high calorie and high fat containing westernized diet accompanied by less physical activity with the socioeconomic transition. Therefore fetal under-nutrition cannot be the sole cause for late onset non-communicable diseases but events that happen later in life could be contributing.

There are many animal studies that have shown nutritional manipulation during certain periods of life, especially in prenatal and early postnatal period affects the metabolism and physique of an individual. Such manipulations have shown to affect adult size, metabolism, blood pressure, lipid and glucose homeostasis, obesity, learning and behavior and life span. Rapid growths in preterm children showed metabolic derangements such as high blood pressure, increase cholesterol, insulin and leptin resistance with significant endothelial dysfunction at 16 year of age (Singhal *et al,* 2004a; Singhal *et al,* 2004b). Similarly when term small for date infants were given enriched formula to promote catch up growth they showed elevated blood pressure and increase fat mass at 8 years of age (Singhal *et al*, 2007). These data substantiated the Singhal and Lucas hypothesis on "Postnatal Growth Acceleration" (Singhal *et al*, 2004b).

The relationship between accelerated infant growth and later obesity has a causal relationship and has been observed in many animal model studies as well as prospective randomized control trials in humans. Infants fed on a nutritionally enriched diet containing 28% or more protein had 30% more body fat at 8 years of age (Singhal *et al*, 2010). Similar observations were made in European Childhood Obesity study (Koletzko

et al, 2009). Therefore first year of life appears to be a critical window of determining later health.

Baired et al in a systematic review looked at the published data on the relationship between postnatal growth and risk of obesity later in life (Baird *et al*, 2005). Based on infant size, the odds of an obese infant to become an obese child at 5-7 years, ranged from 1.5 to 9.38 compared to a normally grown infant. This meta-analysis as a whole shows that infants in the highest end of weight or BMI distribution or had a rapid growth rate during infancy had a greater risk of becoming obese later in childhood or adolescence.

Sri Lanka being a country in economic transition is experiencing transition in socioeconomic status of its people resulting significant behavior change. The increase in purchasing power has made them to adopt high calorie containing westernized diets leading to overweight and obesity. Despite under-nutrition being a public health problem in this country, obesity is an emerging problem. Although it is not uniformly distributed all over the country incidence is on the rise in many urban/semiurban communities. Although Sri Lanka have achieved a lot in the health sector, the prevalence of low birth weight is at a considerably higher level. Subjecting these individuals to a rapid growth in order to reach a higher growth trajectory could lead them to the development of obesity later in life. South Asian populations are well known to have high body fat content to any given BMI value compared to many other ethnic groups, Sri Lankans undoubtedly would have very high fat content in their body predisposing them to develop metabolic complication even at a very young age.

My interest in childhood obesity has grown over the year as it has direct bearing on the development of non-communicable diseases. Cardio metabolic complications due to obesity which lead to the development of NCD are almost non curable, but only controllable. Although the belief existed that they were adult onset illnesses, it is now quite clear there is no age limit. What is important is how long one had been having an adverse body composition before they would develop obesity related metabolic complications. Apart from the physical ailments it causes, the psychological impact it has on a growing child is immense. Furthermore childhood obesity is not seeing by many in the society, both medical fraternity as well as lay community, as a health problem. Therefore I feel it's my duty to highlight this silent epidemic if we are truly interested in controlling non communicable disease in this country.

I have been studying several cohorts of 5-15 year old school children to identify metabolic derangements related to NCD. Also to identify the fat content that would be associated with such metabolic problems and possible anthropometric markers of identifying abnormal fat content associated with metabolic complications. Furthermore to identify any possible relationship of intrauterine growth (denoted by birth weight) to such metabolic complications.

MetS Definition

Normal cutoff values used for metabolic derangements are waist circumference (WC) for age, >90th centile. Unfortunately there are no local cutoffs are available and therefore UK standards are used (McCarthy 2001); abnormal glucose homeostasis if, FBS >100mg/dl or 2 hour OGTT value >140 mg/dl; HDL, <40mg/dl (<1.03 mmol/L); triglyceride, >150mg/dl (≥ 1.7 mmol/L) (Zimmet et al 2007); and blood pressure, >+2SD for age for both SBP or DBP of UK standards (Jackson 2007) once

again as local standards are not available. This cutoff value for SBP and DBP was chosen Instead of the cutoff values given by IDF definition, as the latter value (130/85) is suitable only for the tallest 15 year old child; therefore to prevent under detection of hypertension this was used.

Diagnosis of obesity

A %FM of 35% for girls and 25% for boys was considered as cutoff level for obesity related morbidity. Apart from this, obesity was diagnosed based on BMI cutoffs described by; International Obesity Task Force -IOTF (Cole et al, 2000), and WC cutoff by British Growth standards (1990, revised 1996). BMI based IOTF cutoff values and a BMI two standard deviations above the mean for age and gender on CDC, WHO, British References were considered as obese. As WC also has shown close association with obesity related metabolic consequences, WC was used as a potential obesity diagnostic tool and used both British centile (>90th) (McCarthy et al,2001) and standard deviation (>+2SD) (British Growth References 1990) as obesity cutoff values. Obesity was diagnosed in these populations using newly developed Sri Lankan based BMI and WC cutoff values (Wickramasinghe *et al*, 2011).

Validation

Validity and accuracy of BMI indicators (and WC cutoff values) in the diagnosis of obesity were evaluated by calculating sensitivity, specificity, positive predictive value and efficiency, relative to true obesity diagnosed by absolute %FM (based on BIA technique), using a 2 2 table and method is described elsewhere (Wickramasinghe *et al*, 2005). Furthermore sensitivity and specificity of BMI and WC in diagnosing metabolic derangements were also evaluated using the same technique.

Statistics

Pearson product moment correlation was calculated between anthropometric measures and FM, % FM to determine the association between these and the most suitable anthropometric measure. Significance was considered at $p<0.05$. Data were analyzed using NCSS computer package for windows.

Nutritional statuses were assessed using LMS growth programme (version 2.69, Medical Research Council, UK, 2010).

Anecdotal evidence has shown that childhood obesity is seen in many urban parts of the country. Therefore the interest mounted to study this in different parts of the country.

Colombo District

Nutritional status and metabolic derangement

Nine hundred and twenty school children from colombo district were recruited (boys 547). The sample was segregated according to age (5-10, >10-15 years) to fall in line with IDF definition categories.

The distribution of the nutritional status is shown in table 1. There were 186 (20.2%) with high levels of %FM. Thirty two (3.5%) were obese according to IOTF classification and 193 (21%) had a WC above 90th centile of UK standards. According to Sri Lankan standards, 33.9% and 21.9% of study population had an inappropriately high WC and BMI respectively. About 48% of the population was suffering from thinness according to IOTF classification and 9% was suffering from extreme degree of thinness.

Table 1: Nutritional status according to IOTF classification and other cutoff values.

	5 – 10 years		>10 – 15 years	
	Male	Female	Male	Female
	258	197	289	176
Percentage FM	44(17%)	39(20%)	57(20%)	46(26%)
BMI- IOTF cutoff				
Obese	8(3%)	13(7%)	6(2%)	5(3%)
Overweight	16(6%)	23(12%)	25(9%)	26(15%)
Normal	96(37%)	78(40%)	105(36%)	75(43%)
Thinness				
Thinness 1	75(29%)	38(20%)	79(27%)	29(16%)
Thinness 2	37(14%)	27(14%)	50(17%)	25(14%)
Thinness 3	26(10%)	18(9%)	24(8%)	16(9%)
BMI- SL cutoff values	39(15%)	50(25%)	65(23%)	48(27%)
WC- UK standards	41(16%)	55(28%)	46(16%)	51(29%)
WC- SL cutoff values	58(23%)	67(34%)	115(40%)	72(41%)

Table 2: Distribution of adverse metabolic profile according to age category and sex

	5 – 10 years		11 – 15 years	
	Male	Female	Male	Female
	258	197	289	176
Systolic Blood Pressure	5 (1.9%)	0	0	0
Diastolic Blood Pressure	4 (1.5%)	5 (2.5%)	33 (11.4%)	15 (8.5%)
Fasting Blood Sugar	3 (1.1%)	1 (0.5%)	4 (1.4%)	4 (2.3%)
2 h OGTT	0	0	1 (0.3%)	2 (1.1%)
Cholesterol	28 (10.8%)	40 (20.3%)	32 (11.1%)	39 (22.2%)
Triglyceride	3 (1.1%)	7 (3.5%)	12 (4.2%)	14 (7.9%)
HDL	106 (41.0%)	63 (32.0%)	111 (38.4%)	62 (35.2%)
LDL	47 (18.2%)	48 (24.4%)	42 (14.5%)	39 (22.2%)
MetS (according to IDF definition)	1(0.4%)	3 (1.5%)	4 (1.4%)	5 (2.8%)
Acanthosis	9(3.5%)	12(6.1%)	23(7.9%)	21(11.9%)

Table 2 gives details of the distribution of adverse metabolic profile according to age category and sex. Five (0.5%) and 57 (6.2%) children had Systolic and diastolic hypertension respectively. Twelve (1.3%) and 3(0.3%) had impaired fasting glucose and 2h OGTT respectively. There were 139(15.1%) with high serum cholesterol and with high serum triglyceride and 215(23.3%) with low HDL. Fifteen (1.6%) had metabolic syndrome according to IDF definition.

Table 3 shows the distribution of adverse metabolic derangements in the whole study population as well as categorized according to age groups. 283 (30.8%) had one abnormal metabolic parameter. 95 (10.3%) had two metabolic derangements and 16 (1.7%) had 3 or more metabolic derangements. 161 (43%) girls and 233 (42.6%) boys had at least one metabolic derangement. The distribution of the metabolic derangements is almost equal in both gender groups and with advancing age there is a slight increase in the prevalence. Prevalence of MetS according to IDF definition in the 5-15 year old population is 1.4% and it is higher among females and also in the higher age group .

The prevalence of MetS among obese and overweight children (according to IOTF classification) is 12.5% and 6.6% respectively and among those with a normal BMI was 0.84%. It was not prevalent among thin individuals.

Table 3: Distribution of the number of metabolic derangements of the whole study population and according to each a category of each sex

No of abnormal Metabolic components	Total Population		5-10 year age group		>10-15 year age group	
	Male (547)	Female (373)	Male (258)	Female (197)	Male (289)	Female (176)
0	314(57.4%)	212(56.8%)	154(59.6%)	118(59.9%)	160(55.4%)	94(53.4%)
1	174(31.8%)	109(29.3%)	86(33.3%)	53(26.9%)	88(30.4%)	56(31.8%)
2	52(9.5%)	43(11.5%)	15(5.9%)	23(11.7%)	37(12.8%)	20(11.4%)
3	6(1.1%)	7(1.9%)	2(0.8%)	3(1.5%)	4(1.4%)	4(2.3%)
4	1(09.2%)	2(0.5%)	1(0.4%)	0	0	2(1.1%)
Total no with metabolic derangement	233(42.6%)	161(43.2%)	104(40.4%)	79(40.1%)	129(44.6%)	82(46.6%)

Table 4: Number of obese children (detected by different cutoff methods) with abnormal metabolic components.

No of abnormal Metabolic components	Different methods used to diagnose obesity							
	BMI (Sri Lankan) cutoff		Waist Circumference (Sri Lanka) cutoff		IOTF		%F at Mass	
	Male (104)	Female (98)	Male (173)	Female (139)	Male (14)	Female (18)	Male (101)	Female (85)
0	17(7.3%)	11(6.8%)	52(22.7%)	22(13.7%)	0	1(0.6%)	18(17.8%)	07(8.2%)
1	42(18.0%)	48(29.8%)	71(30.5%)	69(42.8%)	7(3.0%)	6(3.7%)	42(41.6%)	45(52.9%)
2	38(16.3%)	33(20.5%)	43(18.5%)	40(24.8%)	5(2.1%)	9(5.5%)	34(33.7%)	26(30.6%)
3	6(2.5%)	4(2.5%)	6(2.5%)	6(3.7%)	2(0.8%)	2(1.2%)	06(5.9%)	06(7.1%)
4	1(0.4%)	2(1.2%)	1(0.4%)	2(1.2%)	0	0	01(0.9%)	01(1.2%)
Total no with metabolic derangement	87(83.6%)	87(88.8%)	121(69.9%)	117(84.2)	14(100%)	18(100%)	83(82.2%)	78(91.8%)

Except for one child all had inappropriately high body fat mass.

It is important to have robust screening tools to detect children with metabolic derangements early in its development. Therefore there should be sensitive anthropometric tools to detect obesity early. It is always highlighted that international cutoff values to detect obesity is not sensitive in Asian populations and the debate goes on whether they should be brought down to a lower level. We looked at whether locally developed BMI cutoff values are sensitive in detecting metabolic derangements compared to internationally available cutoff values. Table 4 gives the distribution of metabolic derangements according BMI (IOTF and Sri Lankan) cutoff, WC (Sri Lankan) cutoff and %FM categorizations of obesity. Sri Lankan BMI and WC cutoffs were able to detect many cases with metabolic abnormalities than other cutoffs. However, Sri Lankan cutoffs have high false positive rates. Therefore there were many with normal BMI or WC but with abnormal metabolic profile. %FM was able to detect many cases with adverse metabolic outcomes with less false positives.

Table 5 shows the results of validation of different anthropometric cutoff used in the diagnosis of metabolic derangements on Sri Lankan children. In both boys and girls, IOTF obesity cutoff had a very low sensitivity detecting at least a single metabolic derangement. But it had 100% specificity. Sensitivity was improved when the IOTF cutoff was lowered to over-weight level. Sri Lankan based BMI cutoff values improved the sensitivity (37.5% in boys and 54% in girls) with satisfactory level of specificity (>94.4%). The Sri Lanka based WC cutoff values had higher sensitivity better than all tested obesity diagnostic tools, but the specificity was the lowest. Positive prediction value was lowest compared to others but efficiency was equal to other methods. %FM had similar sensitivity to many other cutoff values with higher specificity.

Table: 5: Validity of obesity diagnostic methods in detecting at least one metabolic abnormality.

	IOTF (obesity)	IOTF (over weight & obesity)	BMI Sri Lankan cutoff	WC British cutoff	WC Sri Lankan cutoff	%FM
Male						
Se	6.0%	23.3%	37.3%	37.3%	52.0%	48.4%
Sp	100%	99.7%	94.6%	100%	83.4%	96.7%
Pv	100%	98.2%	83.6%	100%	70.0%	91.8%
Ef	60%	67.1%	70.2%	73.3%	70/0%	75.6%
Female						
Se	10.5%	40.0%	54.0%	66.2%	73.0%	37.2%
Sp	99.5%	98.6%	94.8%	100%	89.6%	94.3%
Pv	94.4%	95.5%	88.8%	100%	80.6%	88.1%
Ef	61.1%	73.2%	77.5%	85.4%	82.5%	70.4%

Se, Sensitivity; Sp, Specificity; Pv, Predictive value; Ef, Efficiency.

Discussion

The concept of metabolic syndrome in children and adolescents is still a matter of discussion, mainly because data on this age group are scarce. There is no consensus regarding the diagnosis of metabolic syndrome in children and adolescents. It is evident that each component of the syndrome must be identified as early as possible in order to prevent definitive lesions. Challenge is to decide on suitable diagnostic criteria and adopting suitable cutoff values to diagnose such metabolic derangements (Halpern 2010).

Chances of developing metabolic derangements and severity of the metabolic consequences depend on how earlier in life they developed and the duration of exposure to the adverse metabolic environment (Halpern 2010). A study done in Brazil involving 720 school-age children found that 8.3% had higher capillary glucose levels among 14 to 19 years old and most of whom were female. (Halpern 2010). Among Sri Lankan children there were 12(1.3%) with impaired fasting glucose while 3(0.3%) had impaired glucose tolerance at 2h OGTT.

In a group of 10-18 year old Mexican children, the MetS prevalence varied between 3.8 to 7.8 % based on different types of definitions. However, it did not use the new IDF definition. The prevalence of metabolic syndrome was 26.1% in obese children and 2.1% in lean individuals (Rodriguez-Moran, 2004). This prevalence was quite similar to the values seen by de Silva et al (2006). However, once again de Silva et al used a diagnostic criterion different to IDF. Among 7-14 year old Chinese children, the prevalence of MetS was 6.6% in the general public and 33.1% among obese children, 2.3% among the lean population (Liu et al, 2010). Both Mexican and Chinese values were more than double compared to our data. Prevalence of MetS according to IDF definition in

this 5-15 year old cohort was 1.4% and among 10-15 year age group, it was 1.7%.

These data clearly shows the prevalence of metabolic syndrome among Sri Lankan children are increasing with advancing age and high among obese individuals or among those with very high levels of body fat. The prevalence depends on the definition used. MetS is prevalent among younger age groups in Sri Lanka and a consensus diagnostic method need to be identified to improve diagnosis.

Insulin resistance

In a sub sample of 309 individuals fasting, and 2 hour post glucose load serum insulin was measured and insulin resistance was measured using HOMA-IR (table 6a). Both fasting and 2 hour post glucose load values were calculated. The fasting insulin levels were almost doubled in the older age group compared to younger age group of same sex. The 2 hour post glucose load insulin levels were more than doubled in the older age group. HOMA-IR was doubled in the older age group denoting that insulin sensitivity is decreasing with advance age. All these were seen with increase in fat content of the body. (Table 6b).

It clearly shows that insulin resistance develops with overweight and obesity.

Table 6: Distribution of Insulin based measures according to (a) age and gender, (b) obesity categorization

(a)	5-10 year		10-15 years	
	Male	Female	Male	Female
N	54	104	79	72
Insulin (fasting) (pmol/L)	29.4±34.8§	24.8±16.7	49.8±39.3	37.8±49.5
Insulin (2h OGTT) (pmol/L)	149.6±162.9*§	92.3±67.7§	416.7±425*.	195.2±201.7
HOMAIR	0.83±1.0§	0.66±0.48§	1.45±1.1	1.1±1.48

*p<0.05 when compared between the two sex groups in each age category or whole group

§ p<0.05 when compared between the two age groups within each gender

(b)	5-10 year			10-15 years		
	Lean	Over-Wt	Obese	Lean	Over-Wt	Obese
N	137	19	10	124	16	3
Insulin (fasting)(pmol/L)	23.8±19.3	45.3±28.9	72.1±79.7*	225.7±251	602±538	1098.5±826.4*
Insulin (2h OGTT) (pmol/L)	124.7±132.9	287.4±226.4	239.5±142.6**	37.444.1	65.6±33.9	147.7±33.3*
HOMAIR	0.67±0.58	1.29±0.86	2.02±2.15*	1.1±1.3	1.91±1.0	4.3±1.6§

* All 3 differ from each other at p<0.05 when compared within each age category, ** Lowest significantly different from the higher 2 value at p<0.05, within each age category, §Highest significantly different from lowest 2 values at p<0.05, within each ageategory

Figure 1 shows the relationship between fasting blood sugar and fasting insulin. Apart from a very few number of children who had impaired fating glucose, majority were managed within normal limits. However, few required high insulin levels to maintain a normoglycaemic state. When the same plot was drawn for 2 hour RBS of OGTT test and insulin levels (figure 2), apart from few children with impaired glucose tolerance, majority were well controlled. However the insulin requirement had been very high in order to maintain a normoglycaemia.

Figure 1: Relationship between fasting blood sugar and insulin level.

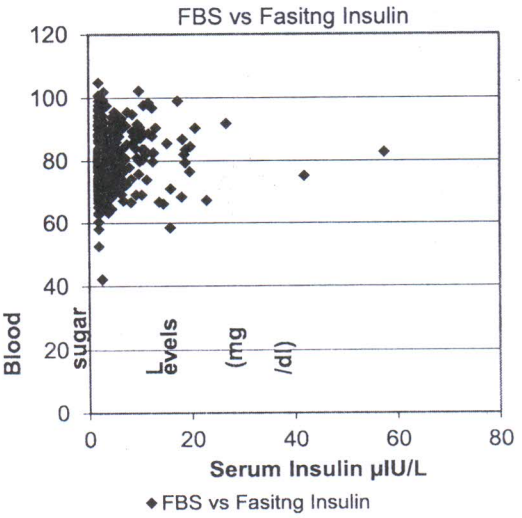


Figure 2: Relationship between random blood sugar and insulin 2 hour post glucose load.

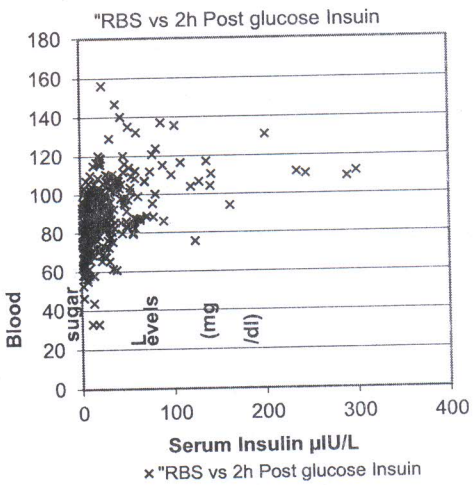
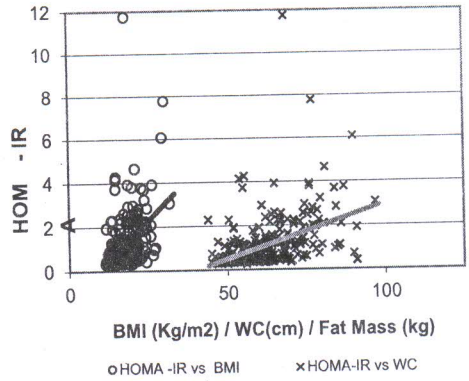


Figure 3 shows the changes that occur in HOMA-IR in relation to changes in BMI, WC. A steady rise in HOMA-IR is noted with increase in each of the measured parameters.

Figure 3: Relations hip between HOMA-IR and Anthropometric measures



Discussion

Our data clearly shows that the insulin secretion in the fasting and fed state are quite high and is similar to the values shown in South Asian migrants living in the UK (Whincup 2002). It clearly shows that with increase in age and increase in adiposity leads to secretion of high insulin levels in order to maintain a normoglycaemia. Insulin levels in girls were slightly lower than in boys which probably a reflection of early development of insulin resistance in boys resulting in many cardiovascular risks later in life. Higher levels of deranged metabolic parameters indicate that insulin probably has a relationship to their aetiology.

High levels of post prandial insulin levels in the light of normoglycaemia indicate that much before impairment of blood sugar levels appear the insulin levels becomes high in order to maintain normoglycaemia. Therefore use of insulin as a screening tool for insulin resistance is highlighted by this study as much as it had been done by other researchers (Viner et al, 2005; McAuley, 2001).

Obesity Diagnosis

Asian populations are well known to have a higher level of fat to any given value of BMI. Therefore the best BMI cutoff values or any other anthropometric cutoff value is of paramount importance in the detection of obesity. The correlation coefficients (r) for BMI, BMI-Z and FM, %FM were calculated. The relationship between BMI and FM was high compared to the relationship between BMI and %FM. Similar association was seen between BMI-Z and FM. The relationship between WC, with FM was higher than with %FM. All these associations were statistically significant ($p<0.001$). Association between WHR(waist hip ratio) and FM as well as %FM was poor, but the association between WHR and FM as

well as %FM was statistically significant and was stronger with latter. Anthropometric measures had a strong association with FM than with %FM.

Table 7 shows the number of individuals diagnosed as obese based on 9 different cutoff values available in the published literature. Absolute FM assessed by BIA technique based on 2-compartment model was used as the reference. A high proportion of girls (22.5%) had %FM that would be associated with adverse health outcomes (obese), compared to boys (18.5%). The IOTF BMI based cutoff detected 18 (4.8%) girls and 14 (2.5%) boys as obese. Number of obese cases detected by WHO, British growth standards and Centre for Disease Control, Atlanta, USA (CDC) were little higher than the number detected by IOTF cutoff values. WC measures were able to diagnose more cases of obesity than BMI based cutoff values in this group of children. The newly developed Sri Lankan BMI standards were able to detect 98 (26.3%) girls and 104 (19.0%) boys as obese. Sri Lankan WC cutoff values determined children as obese even more than the cases detected by %FM cutoff value.

Table 8 shows the results of validation of each method used in the diagnosis of obesity in Sri Lankan children. In both boys and girls, the BMI based international cutoff had a very low sensitivity ranging from 11.9 to 32.9%, but high specificity (>98.6%). The positive predictive value was more than 84% in both groups and efficiency was also high ranging between 79.9-86.7% in both groups. Diagnosis of obesity based on international WC cutoff showed high specificity but low sensitivity.

Table 7: Prevalence of obesity diagnosed by different anthropometric measures

	Female (373)	Male (547)
Obesity by;	n (%)	n (%)
%FM	85(22.8)	101(18.5)
IOTF cutoff values	18(4.8)	14(2.5)
BMI-Z >2SD(WHO)	32(8.6)	32(5.8)
BMI-Z >2SD(British)	26(6.9)	28(5.1)
BMI-Z >2SD(CDC)	12(3.2)	13(2.4)
WC-Z >2SD (British)	67(17.9)	46(8.4)
WC >90th centile (British)	106(28.4)	87(15.9)
BMI (Sri Lanka)	98(26.3)	104(19.0)
WC (Sri Lanka)	139(37.3)	173(31.6)

Table: 8: Validation of anthropometric measures as indicators of obesity

	IOTF	BMI-Z >2SD (WHO)	WC Z >2SD (British)	BMI (Sri Lanka)	WC (Sri Lanka)
Male					
Se	12.9	29.7	42.6	78.2	93.1
Sp	99.8	99.6	99.3	94.4	82.3
Pv	92.9	93.7	93.5	76.0	54.3
Ef	83.7	86.7	88.8	91.4	84.3
Female					
Se	18.8	32.9	70.2	83.5	95.3
Sp	99.3	98.6	97.2	90.6	79.7
Pv	88.9	87.5	88.1	72.4	58.3
Ef	81.0	83.6	91.1	89.0	83.3

Se, Sensitivity; Sp, Specificity; Pv, Predictive value; Ef, Efficiency.

The Sri Lankan based BMI cutoff values had higher sensitivity in detecting obese patients compared to the available international cutoff values in both gender groups (Table 8). Although the sensitivity was lower than the other BMI based cutoff values, it was more than 90% in both gender groups. The positive predictive value was low but the efficiency was better than other BMI based cutoff values. The Sri Lanka based WC cutoff values had higher sensitivity better than all tested obesity diagnostic tools, but the specificity was the lowest. Positive prediction value was lowest compared to other but Efficiency was equal to other methods.

Discussion

As far as the onset of non-communicable diseases are concerned, body composition of children is important. Fatness in childhood and adolescence persists into adulthood and it grows stronger with age. Adverse metabolic profile shows a cumulative effect over the years, beginning from younger age.

Ideally, obesity should be diagnosed and followed up based on the absolute fat measurement of body. However, there is still no consensus developed on the exact percentage body fat that could be linked to adverse metabolic profile although %FM of about 25% in male and 35% in girls are considered to be reasonable cutoff values. Anthropometry based methods such as BMI and WC are the best alternatives especially to be used as less time consuming screening tools. Furthermore, cutoff values whether internationally available or country specific or ethnic specific in multiethnic populations needs more research.

Duncan and co-workers (2005) showed that the IOTF cutoff had high specificity (100%) in detecting obesity in Indian children but low sensitivity (54.5%). Similar results were seen for Pacific Island children

also. Therefore, Duncan *et al.* (2005) concluded that IOTF BMI base cutoff values are not suitable for diagnosis of obesity in Indian and Pacific Island children and as such, ethnic-specific cutoff values would be more appropriate in assessing obesity in multi-ethnic populations such as in New Zealand.

In our data set, prevalence of obesity based on the available international cutoff values were relatively low and this could erroneously delay detection of cases with adverse body composition, which is related to many adverse metabolic outcomes. Although the Sri Lankan based cutoff values had low specificity, it could be argued that having such a low threshold to detect such cases would provide adequate time to adopt adequate correction measures. Naturally a screening tool should have high sensitivity, and even if it has low specificity, it will not interfere with management. Once cases with potential risk are identified, more definitive techniques for detecting absolute fat content of body as well as screening for metabolic derangements could be done, which would have a positive impact on health rather than a negative effect. Furthermore the first step in the management is noninvasive behavioral changes which will pave the way to adoption of healthy lifestyle.

IOTF cutoff values have under-estimated the prevalence of obesity in many populations. Therefore, although it was considered to be an internationally valid cutoff value it has shown lack of promise. A drawback of IOTF cutoffs is that although it has a large data set from six countries, it did not have a fair representation from Asia especially South Asia region. Therefore, whether IOTF cutoff values are truly international and could be applied universally is of doubt.

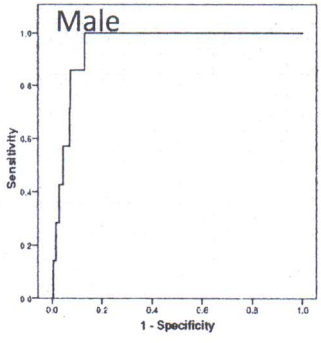
WHO technical report (WHO 2000) acknowledged that BMI

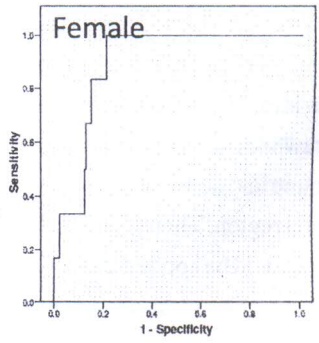
cutoff values for overweight and obesity may not correspond to the sam degree of fat content across different populations. Therefore, populatio specific rather than universal BMI cutoff values should be use (Deurenberg et al, 1998). This study clearly shows that ethnicit influences body composition and south Asian children have high f content at a low BMI. In view of its low sensitivity in diagnosing obesit best would be either to revise BMI cutoff values to suit a populatio ethnic group or make a definitive assessment of fat content of body an diagnose obesity based on that.

Determination of %FM associated with Metabolic Syndrome

According to the ROC curves drawn irrespective of the ages c participants, MetS was associated with a %FM of 28.6 (sensitivity 0.85 specificity 0.87) in boys and 33.6 (sensitivity 0.833; specificity 0.8) i girls (Figure 4). Two or more (≥ 2) metabolic abnormalities wer associated with a %FM of 17.1 in boys and 25.7 in girls. These finding ar keeping with the internationally published data.

Figure 4: ROC curves to determine %FM associated with MetS





	Area	Std Error	Asymptotic Sig	Asymptotic 95% Confidence Interval	
				Lower Bound	Upper Bound
Male	0.047	0.017	0.000	0.914	0.980
Female	0.895	0.032	0.001	0.832	0.959

Impact of Early Nutrition on Development of Obesity and Related Morbidity

A sample of 833 children (boys 494) was studied to assess the relationship between metabolic derangements and birth weight. Sample was stratified by age (5-10 yrs and >10-15 yrs) and each group was categorized to tertiles of birth weight and present BMI. Based on these two parameters 3×3 table was constructed for the mean of the measured metabolic parameters. Metabolic parameters were analyzed in each age group according to the categories formed by birth and current BMI tertiles.

In the >10-15 year old age group also similar abnormalities were noted. Metabolic derangements in the lowest birth and highest current BMI tertile (%FM 32.6%; SBP 109.5mmHg; DBP 67.2mmHg; RBS 93.1mg/dl; Cholesterol 169.7 mg/dl; TG 98.5mg/dl; HDL 43.9mg/dl LDL 106.1mg/dl) were significantly impaired than those in lowest birth and lowest current BMI tertile (%FM 16.1%; SBP 97.9mmHg; DBP 60.5mmHg; RBS 85.4mg/dl; Cholesterol 162.8 mg/dl; TG 72.7mg/dl; HDL 53.3mg/dl LDL 94.9mg/dl).

In the 5-10 year age category similar pattern of distribution was noted, significant metabolic abnormalities were noted in the lowest birth and highest current BMI tertile category (%FM 27.8%; SBP 95.9mmHg; DBP 59.8mmHg; RBS 92.1mg/dl; Cholesterol 176.1 mg/dl; TG 83.6mg/dl; HDL 47.3mg/dl LDL 111.6mg/dl) than those who were in

lowest birth and lowest current BMI tertile (%FM 14.0%; SBP 87.7mmHg; DBP 53.5mmHg; RBS 87.5mg/dl; Cholesterol 158.7 mg/dl; TG 63.4mg/dl; HDL 54.9mg/dl LDL 91.1mg/dl).

Clear differences were noted among HDL, TG, blood pressure and body fat mass. The body fat mass in the low birth tertile and highest current BMI tertile was very high compared to other two current BMI tertiles in the same birth weight tertile (ie the lowest birth weight tertile). This denotes that our children put on weight by assimilating fat in the body rather than growing in all areas of body composition.

When the group was divided into 3 groups based on the birth weight (tertiles), no significant difference was noted in the metabolic parameters across each other. That is between the lowest birth weight and highest birth weight tertile. However, the group was divided into 3 groups (tertile) based on the current BMI and compared, those in the highest BMI tertile had significantly impaired metabolic profile than the other two. Mean %FM increased across BMI tertiles denoting that children gain weight mainly due to accumulation of fat. Fasting insulin, 2 hour post glucose load insulin and HOMA-IR were also categorized according to birth weight and current BMI tertiles. Similar distribution was seen (table 9a-c).

Table 9a: Mean fasting serum insulin levels for birth and current BMI tertile groups and overall mean value the BMI and birth weight tertiles separately for 5-10 and 10-15 year old age categories

		5-10 years				10-15 years			
		BMI tertile				BMI tertile			
		T1	T2	T3		T1	T2	T3	Total
Birth weight tertile	T3	16.5±8.6	20.5±9.1	33.2±16.6	23.1±13.8	28.5±29.4	35.8±18.7	69.9±34.0	43.9±34.2
	T1	21.9±23.5	26.2±25.6	40.9±28.8	28.4±26.3	19.7±8.5	49.6±92.5	72.6±52.6*	46.3±65.2
	T2	14.3±0.9	30.3±33.3	47.6±64.5*	32.6±46.2	23.4±16.8	38.9±30.6	56.6±24.4	41.8±28.2
		17.7±14.8	25.6±24.4	40.7±43.3§		24.4±21.6	42.3±60.4	66.1±38.2§	

§significantly differ from over all mean for first and second (T1 & T2) BMI tertiles.

*significantly high ($p<0.05$) than the lowest 2 values ,** significantly high ($p<0.05$) than the lowest value

Table 9c: Mean HOMA IR levels for birth and current BMIertile groups and overall mean value for the BMI and birth weight tertiles separately for 5-10 and 10-15 year old age categories

		5-10 years				10-15 years			
		BMI tertile				BMI tertile			
		T1	T2	T3	Total	T1	T2	T3	Total
Birth weight tertile	T3	0.44±0.21	0.57±0.30	0.95±0.51	0.65±0.42	0.81±0.79	0.95±0.46	2.1±1.0	1.2±1.0
	T1	0.56±0.48	0.80±0.92	1.20±0.94	0.82±0.82	0.57±0.27	1.42±2.7	2.2±1.7*	1.35±1.94
	T2	0.38±0.05	0.85±1.0	1.29±1.70*	0.89±1.3	0.70±0.53	1.2±0.96	1.6±0.71	1.2±0.86
	Total	0.47±0.31	0.74±0.80	1.1±1.2		0.71±0.60	1.22±1.8	1.9±1.2§	

§significantly differ from over all mean for first and second (T1 & T2) BMI tertiles.

Significantly differ from over all mean for first (T1) BMI tertile

$^{"}$ significantly high ($p<0.05$) than the lowest 2 values *, significantly high ($p<0.05$) than the lowest value

Discussion

Most of the data have shown that those who were born big and remain big or those who were born small and remain small are less likely to suffer from adverse metabolic consequences than those who were born small but become big later. Therefore as much as providing nutrition is important, it is also important to provide them with some control, not too less and not too much. Bhargava and coworkers quite eloquently elaborated in their study from India, how thin individuals at birth, when began to cross BMI centiles upwards during childhood ended up having impaired glucose tolerance as young adults (Bhargava *et al*, 2004). Data of Sri Lankan children also have shown that abnormal cardiovascular risk is seen among those of the lowest birth tertile and highest current BMI tertile even at 5-10 age groups and it is more clear in older age groups (10-15 years). Those born and currently having a BMI in the lowest tertile are much more protected. Therefore big is not good always and if born small should try to be small to enjoy better health.

Table 9b: Mean 2h OGTT serum insulin levels for birth and current BMI tertile groups and overall mean value for the BMI and birth weight tertiles separately for 5-10 and 10-15 year old age categories

		5-10 years				10-15 years			
		BMI tertile				BMI tertile			
		T1	T2	T3	Total	T1	T2	T3	Total
Birth weight tertile	T1	85.3±73.6	98.1±52.2	250.7±220.4*	143.1±154.2	156.7±141.1	261.5±145.3	577.6±465*	320.3±343.3
	T2	75.2±60.6	111.5±60.0	211.2±219.8	123.8±130.7	173.8±133.0	241.8±267.9	636.8±567.7**	339.8±405.4
	T3	58.9±40.1	67.3±48.3	230.4±199.4*	130.2±152.8	118.7±70.2	186.9±141.5	318.3±190.5	217.5±166.2
	Total	75.0±62.7	94.0±56.2	232.9±208.3§		154.8±126.0	225.0±199.0	512.5±449.7§	

§significantly differ from over all mean for first and second (T1 & T2) BMI tertiles.

*significantly high ($p<0.05$) than the lowest values, **significantly high ($p<0.05$) than the lowest 2 values

Negambo Education zone

Nutritional status

A cross-sectional descriptive study of 13272, 5-15 year old school children from Negambo education (boys=5607) was carried out during 2013-2014 period. Of the population 13.9% girls and 21.3% boys were wasted. 11.1% girls and 9.5% boys were overweight while 4.3% girls and 5.8% boys were obese. 5.8% girls and 7.3% of boys were stunted. 15.8% of boys had a %FM >28% and 24.5% girls had a %FM >32% which was considered as obese in the respective sex groups. Waist to height ratio >0.5, which is considered to be a marker of central obesity was seen among 11% of boys and 8% of girls. Although a significant proportion of the population had high fat content in the body, the WHO BMI cutoff value was not sensitive in detecting them timely.

Therefore while wasting is still high among children in the Negambo education zone area, overweight and obesity rates appear to be similar to Colombo. Stunting rates are lower than national figures. Under-nutrition is worse in boys. Although overweight and obesity rates are similar in both gender groups more females had adverse levels of accumulation of fat in the body. Furthermore the currently available BMI cutoff values are not sensitive in detecting obesity in this group of children. Although Negambo can be considered a semi urban area of Sri Lanka, it has been affected by over-nutrition as much as by under-nutrition. Changes in the life style and diet in response to social and cultural changes may have resulted in these changes.

Insulin Resistance among Overweight/Obese children

Insulin resistance is high among South Asian populations starting from a young age as it was seen among Colombo children. Poor intrauterine growth combined with rapid postnatal growth, predisposes to

develop insulin resistance later in life. Insulin resistance was studied among 8-16year old overweight/obese school children from Negambo educational zone.

Two hundred and sixty four children were studied (boys 137). Of them 46 were overweight and 218 obese. There were 6 (2%) children with DM (Diagnosis by; FBS-1, 2h OGTT-4 and FBS+ OGTT-1). 17 had IFG, 27 had IGT and 8 had both IFG and IGT (16.3% prediabetic state).

The mean(SD) fasting insulin was 14.0(12.6) mU/L and 14.4(16.8) mU/L($p>0.05$) in girls and boys respectively. 2 hour post glucose insulin (2hPGI) in girls and boys were 87.8(62.1)mU/L and 75.6(66.7)mU/L($p>0.05$) respectively. The mean HOMA-IR was 3.03(2.85) and 3.23(4.13)($p>0.05$) for girls and boys respectively and 3.14(3.3) and 3.10(3.6)($p>0.05$) in overweight and obese children respectively. 2hPGI was 59.7(41.3) mU/L and 86.1(67.7) mU/L ($p<0.05$) for overweight and obese children.

2h post glucose insulin and HOMA-IR increased with the increase in the number of abnormal metabolic parameters. HOMA-IR showed statistically significant correlation with BMI, WC, FM and WC to Height ratio(WHtR). 2hPGI levels showed stronger correlation with BMI, WC, WHtR, FM, %FM.

This shows that a significant number of children in this group had abnormal glucose homeostasis as much as it was shown in children from Colombo. 2h post glucose insulin (PGI) level appears to be a better marker in identifying metabolic derangements early than fasting insulin/HOMA-IR. This could be due to the objective response that occurs to a measured glucose load and could be the first step in developing IR. It would be useful to develop a screening tool using 2hPGI levels.

Conclusions

Many Sri Lankan children are seen to develop abnormal metabolic profiles at a very younger age and many of them have metabolic derangements despite having normal BMI, WC and %FM levels. This denotes that at lower anthropometric cutoff values metabolic derangements are prevalent in this population and more research is needed to identify the appropriate cutoff values to suit this population. This study shows that rise in BMI leads to deranged metabolic parameters even at a younger age. Low birth weight independently is not a risk factor to have abnormal metabolic profile in childhood, but a gain of high BMI later in life, is associated with many metabolic derangements, than those who were born small and remain small. This favours the accelerated post-natal growth hypothesis. Most gain weight by disproportionately accumulation fat rather than shown a true growth in all body components ie bone, skeletal muscles, soft tissue and fat.

Future Direction.

In order to control NCD's in the future, optimum growth is of paramount important which could be considered as a primodial preventive measures. With the assistance of growth charts, anthropometry is used to identify the optimum growth. However, labeling one's growth as normal or abnormal using standard growth chart cutoff values is conceptually flawed since these charts identify a statistical comparison of growth with others in a population rather than identifying a "desirable growth" in terms of health outcomes based on individual's potential to grow. Therefore growth charts should be used as references but not as standards. They do not categorize individuals according to their CVD risk or cognitive potentials. We know very little about the aspects of growth and related body composition. Knowing these exactly have major relevance to public health issues especially in an era where NCD are in epidemic proportion and evidence is gathering to the relationship between patterns of early growth and later diseases.

Therefore nutrition should be provided with a control. Periodic growth monitoring should be done to identify the proper growth trajectory. In a public health setting therefore the most prudent is to have proper growth monitoring and recording. In regions where under nutrition had been a significant problem, the mindset of the caring health worker is to see upward crossing of centiles, which considered to as a "beneficial" effect as well as a reflection of success in management. However, now it is quite clear neither is true in the long term. Therefore close monitoring and correction of growth in early years of life is very important. The most prudent would be to guide the new born to continue its growth in the same trajectory as they had prenatally. Therefore the best would be to allow the newborn to grow along their birth centile line. Plotting the birth weight appropriately against the gestational age and continuing along that line assuming that was the trajectory of growth child had since conception, would be the most prudent action to take by carers in the light of available evidence. Respecting and allowing them to grow along their birth centile will help to have a neurologically, metabolically and physically sound individual. Growing along their birth centile would be the closest to the natural trajectory that he/she should be growing. Therefore a constant dialogue need to be built between clinicians, parents, community carers, policy makers about these facts and more importantly with non-governmental organizations who keep on interpreting data out of scientific context, thus introducing programmes which could be more harmful than beneficial in the long term.

It is of paramount importance to develop appropriate screening tools for community use for early detection of abnormal metabolic profiles in order to make NCD prevention more meaningful.

Childhood obesity in Sri Lanka is a silent epidemic which is growing day by day unnoticed. NCD related complications are seen among Sri Lankan child beginning from a very young age, therefore it is important to put more emphasis on detecting childhood obesity early and taking steps to prevent them.

Truly speaking prevention of NCD begins from the antenatal period where good intrauterine growth is promoted followed by proper nutrition and growth monitoring thus enabling healthy growth.

Acknowledgements

I am grateful to all children and their parents for participating in this study.

I had the privilege of working with 2 teams at two different locations. the colleagues of the colombo team were Dr. Carukshi Arambepola assisted me in designing this project and in statistical analysis. Drs. P. Bandara, M. Abeysekera, S. Kuruppu, P. Dilshan and BS. Dissanayake assisted in data collection. Nursing officers of Professorial Paediatric Unit of Lady Ridgeway Hospital for the assistance in drawing up blood from the children. Mr. Dissanayake of the Clinical Laboratory of Professorial Paediatric Unit of Lady Ridgeway Hospital for preparing samples for analysis. Ms. Amara Wijerathna and Ms. A. U. A. Gunawardana of the Biochemistry Laboratory of the Department of Obstetrics and Gynaecology in analyzing the blood samples.

Nembers of the Negambo team were Drs. LS Warnakulasuriya, MAM Fernando, AVN Adikaram, ARM Thawfeek, WML Anurasiri, in data collection and conducting the study. Dr. D Samaranayake in statistical analysis.

Mr. Sheran Weerasinghe in managing the cohort.

References

Alberti K, Zimmet P, Consultation W. Definition diagnosis and classification of diabetes mellitus and its complications. Part 1: diagnosis and classification of diabetes mellitus, provisional report of a WHO consultation. *Diabetic Medicine.* 1998;15: 539-553.

Alberti, KGMM, Zimmet P, Shaw J. Metabolic syndrome a new world wide definition. A concensus statement from the international diabetes federation. *Diabetic Medicine.* 2006;23:469-480.

Anand SS, Razak F, Vuksan V *et al.* Diagnostic Strategies to detect glucose intolerance in a multiethnic population. *Diabetes Care.* 2003;26:290-296.

Anderson PJ, Critchley JAJH, Chan JCN, *et al.* Factor analysis of the metabolic syndrome: obesity vs insulin resistance as the central abnormality. *International Journal of Obesity.* 2001;25:1782-8.

Aristinuno GG, Foster JA, Voor AW, Sirinivasan SR, Berenson GS. Influence of persistent obesity in children on Cardiovascular risk factors: the Bogalusa Heart Study. *Circulation.* 1984;69:895-904.

Baird, J; Fisher, D; Lucas, P; Kleijnen, J; Roberts, H; Law, C. Being big or growing fast: systematic review of size and growth in infancy and later obesity. *British Medical Journal.* 2005;331:929-34.

Balkan B, Kwasnik L, Miserendino R, Holst JJ, Li X. Inhibition of dipeptidyl peptidase IV with NVP-DPP728 increases plasma GLP-1 (7-36 amide) concentrations and improves oral glucose tolerance in obese Zucker rats. *Diabetologia.* 1999;42:1324-1331.

Barker, DJP. *Mothers, Babies and Diseases in later life*. London: BMJ Publication; 1994.

Barker, DJP; Osmond, C; Golding, J; Kuh, D; Wadsworth, MEJ. Growth in utero, blood pressure in childhood and adult life, and mortality from cardiovascular disease. *British Medical Journal.* 1989;298:564-567.

Barker, DJP; Osmond, C; Simmonds, SJ; Wield, GA. The relation of small head circumference and thinness at birth to death from cardiovascular disease in adult life. *British Medical Journal.* 1993;306:422-6.

Bhargava, SK; Sachdev, HS; Fall, CHD; Osmond, C; Lakshmy, R; Barker, DJP; Dey Biswas, SKD; Ramji, S; Prabhakaran, D; Reddy, KS. Relation of Serial Changes in Childhood Body-Mass Index to Impaired Glucose Tolerance in Young Adulthood. *New England Journal of Medicine.* 2004; 350 (9): 865-875.

Bjorntorp P. Portal adipose tissue as a generator of risk factors for cardiovascular disease and diabetes. *Atherosclerosis.* 1990;10:493-496.

Carr DB, Utzschneider KM, Hull RL *et al.* Fish BE, Knopp RH, Kahn SE. Intra-abdominal fat is a major determinant of the National Cholesterol Education Program Adult Treatment Panel III criteria for the metabolic syndrome. *Diabetes*. 2004;53(8): 2087-94.

Chan DFY, Li AM, Chu WCW *et al.* Hepatic steatosis in obese Chinese children. *International Journal of Obesity Related Metabolic Disease.* 2004;**28(10)**: 1257-63.

Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. 2000. Establishing a standard definition for child overweight and obesity world wide: International survey. *BMJ* 320:1-6.

De Silva KSH, Wickramasinghe VP, Goonerathne INA. Metabolic consequences of childhood obesity – a preliminary report. *The Ceylon Medical Journal.* 2006;**51(3)**:105-109.

Deurenberg P, Yap M, Van Staveren WA. Body mass index and percentage body fat: a meta analysis among different ethnic groups. International Journal of Obesity 1998; 22: 1164-71.

Duncan JS, Schofield G, Duncan EK, Rush EC. Classifying childhood obesity in a multiethnic population: comparisons among five major ethnic groups. O27 Abstract. *International Journal of Body Composition Research.* 2005;3(3):89.

Dunstan DW, Zimmet PZ, Welborn TA. *et al.* The rising prevalence of diabetes and impaired glucose tolerance: the Australian Diabetes, Obesity and Lifestyle Study. *Diabetes Care.* 2002;25:829-834.

Dwyer T, Blizzard CL. Defining obesity in children by biological endpoint rather than population distribution. *International. Journal of Obesity and Related Metabolic Disorders.* 1996;20:472-480.

Ebbeling CB, Pawlak DB, Ludwig DS. Childhood obesity: public-health crisis, common sense cure. *Lancet.* 2002;360(9331):473-82.*England Journal of Medicine.* 2004;350:2362-74.

Freedman DS Khan LK, Dietz WH, Srinivasan SR, Berenson GS. Relationship of childhood obesity to coronary heart disease risk factors in adulthood: the Bogalusa Heart Study. Pediatrics. 2001; 108(3):712-8.

Freedman DS, Sirinivasan SR, Harsha DW, Webber LS, Berenson GS. Relation of body patterning to lipid and lipoprotein concentrations in children and adolescents: the Bogalusa Heart study. *American Journal of Clinical Nutrition.* 1989;50:930-939.

Grundy SM, Brewer HB, Cleeman JI, Smith SC, Lenfant C. 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;109:433-438.

Hales, CN; Barker, DJ; Clark, PM; Cox, LJ; Fall, C; Osmond, C; Winter, PD. Fetal and infant growth and impaired glucose tolerance at age 64. *British Medical Journal.* 1991;303:1019-22.

Halpern A, Mancini MC, Magalhães MEC, Fisberg M, Radominski R, Bertolami MC, Bertolami A, de Melo AD, Zanella MT, Queiroz MS, Nery M. Metabolic syndrome, dyslipidemia, hypertension and type 2 diabetes in youth: from diagnosis to treatment. Diabetology & Metabolic Syndrome 2010, 2:55

Jackson LV, Thalange NKS, Cole TJ. Blood pressure centiles for Great Britain. Archives Disease Child. 2007;92:298-303.

Keskin M, Kurtoglu S, Kendirci M, Atabek ME, Yazici C. Homeostasis model assessment is more reliable than the fasting glucose/insulin ratio

and quantitative insulin sensitivity check index for assessing insulin resistance among obese children and adolescents. *Pediatrics.* 2005;115(4):e500-e503.
URL: www.pediatrics.org/cgi/doi/10.1542/peds.2004-1921. Accessed on 19th June 2006.

Koletzko, B; von Kries, R; Closa, R; Escribano, J; Scaglioni, S; Giovannini, M; Beyer, J; Demmelmair, H; Gruszfeld, D; Dobrzanska, A; Sengier, A; Langhendries, J; Cachera, MR; Grote, V for the European Childhood Obesity Trial Study Group. Lower protein in infant formula is associated with lower weight up to age 2 y: a randomized clinical trial. *American Journal of Clinical Nutrition.* 2009;89:1-10.

Krishnaswamy, K; Naidu, AN; Prasad, MPR; Reddy, GA. Fetal Malnutrition and Adult Chronic Disease. *Nutrition Reviews* 2002;60(5):(Suppl. II)S35–S39.

Lithell, HO; McKeigue, PM; Berglund, L; Mohsen, R; Lithell, U; Leon, DA. Relation of size at birth to noninsulin dependent diabetes and insulin concentrations in men aged 50-60 years. *British Medical Journal.* 1996;312:406.

Liu KH, Chan YL, Chan WB, Kong WL, Kong MO, Chan JCN. Sonographic measurement of mesenteric fat thickness is a good correlate with cardiovascular risk factors: comparison with subcutaneous and pre-peritoneal fat thickness, magnetic resonance imaging and anthropometric indexes. *International Journal of Obesity Related Metabolic Disease.* 2003;**27**:1267-1273.

Liu W, Lin R, Liu A, Du L, Chen Q. Prevalence and association between obesity and metabolic syndrome among Chinese elementary school children: a school-based survey. BMC Public Health 2010, 10:780.

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.

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

Mcauley KA, Williams SM, Mann JI, Walker RJ, Lewis-Barned NJ, Temple LA, Duncan AW (2001). Diagnosing Insulin Resistance in the General Population. Diabetes Care 24:460–464.

McCarthy HD, Jarrett KV, Crawley HF. The development of waist circumference percentiles in British children aged 5.0-16.9yrs. *European Journal of Clinical Nutrition.* 2001;55(10):902-7.

National Cholesterol Education Programme/ Adult Treatment Panel III (NCEP/ATP III). Executive summary of Third Report of the Expert Panel on Detection Evaluation and Treatment of high blood cholesterol in adults. *Journal of American Medical Association.* 2001;285:2486-2497.

Osmond, C; Barker, DJP; Winter, PD; Fall, CHD; Simmonds, SJ. Early growth and death from cardiovascular disease in women. *British Medical Journal.* 1993;307:1519-24.

Rexrode KM, Carey VJ, Hennekens CH, *et al.* Abdominal Adiposity and Coronary Heart Disease in Women. *Journal of American Medical Association.* 1998;280:1843-1848.

Rich-Edwards, JW; Stampfer, MJ; Manson, JE; Rosner, B; Hu, FB; Michels, KB; Willett, WC. Breastfeeding during infancy and the risk of cardiovascular disease in adulthood_Hlt285461503._ Hlt285461503 *Epidemiology.* 2004 Sep; 15 (5) : 550-6.

Rodriguez-Moran M, Salazar-vazquez B, Violante R, Fernando Guerrero-Romero F. (2004). Metabolic Syndrome among Children and Adolescents aged 10–18 Years. Diabetes Care. 2004;27(10): 2516-7.

Ruige JB, Assendelft WJ, Dekker JM, Kostense PJ, Heine RJ, Bouter LM. Insulin and risk of cardiovascular disease: a meta-analysis. *Circulation* 1998;97:996-1001.

Saad MF, Lillioja S, Nyomba BL, Castillo C, Ferraro R, De Gregorio M, Ravussin E, Knowler WC, Bennett PH, Howard BV et al. Racial differences in the relation between blood pressure and insulin resistance. *New England Journal of Medicine.* 1991;324(11):733-9.

Singhal, A. Does early growth affect long –term risk factors for cardiovascular disease?. In Lucas A, Makrides M, Ziegler EE editor. *Importance of Growth for Health and Development.* Nestle Nutrition Institute Workshop Series Pediatric Programme, Vol 65. Switzerland. Karger. 2010:41-54.

Singhal, A; Cole, TJ; Fewtrell, M; Deanfield, J; Lucas, A. (2004a).Is slower early growth beneficial for long term cardiovascular health? *Circulation.*109:1108-1113.

Singhal, A; Lucas, A (2004b). Early origins of cardiovascular disease. Is there a unifying hypothesis? *Lancet.* 363:1642-1645.

Singhal, A; Cole, TJ; Fewtrell, M;Kennedy, K; Stephenson, T; Elias-Jones, AL; Lucas, A (2007) Promotion of faster weight gain in infants born small for gestational age: is there an adverse effect on later blood pressure? *Circulation.*;115:213-220.

Stein, CE; Fall, CH; Kumaran, K; Osmond, C; Cox, V; Barker, DJ. Fetal growth and coronary heart disease in South India. *Lancet* 1996;348:1269-73.

Tan KCB, Wat NMS, Tam SCF, Janus ED, Lam TH, Lam KSL. C-reactive protein predicts the deterioration of glycaemia in Chinese subjects with impaired glucose tolerance. *Diabetes Care*.2003;26:2323-2328.

Viner PM, Segal TY, Licharnwicz-Krynska E, Hindmarsh P, Prevalence of the insulin resistance syndrome in obesity. *Archives of Diseases in Childhood.* 2005;90:10-14.

Voors AW, Harsha DW, Webber LS, Radhakrishnamurthy B. Srirnivasan SR, Berenson GS. Clustering of anthropometric parameters, glucose tolerance and serum lipids in children with high and low β– and pre β-lipoprotein in children: the Bogalusa Heart study. *Arteriosclerosis.* 1982;2:346-355.

Weiss R, Dziura J, Burget TS. Obesity and the metabolic syndrome in children and adolescents. *New England Journal of Medicine.* 2004; 350:2362-2374

Whincup RH, Gilg JA, Papacosta O.Early evidence of ethnic difference in cardiovascular risk: cross sectional comparison of British South Asian and white children. *British Medical Journal.*2002;324:16.

WHO Obesity; Preventing and managing the global epidemic. WHO Technical Report Series 894, WHO Geneva. 2000.

Wickramasinghe VP, Cleghorn GJ, Edmiston KA et al. 2005. Validity of BMI as a measure of obesity in Australian white Caucasian and Australian Sri Lankan children. Ann Hum Biol 32: 60-72

Wickramasinghe VP, Lamabadusuriya SP, Atapattu N, Sathyadas G, Kuruparanantha S, Karunarathne P. Nutritional status of schoolchildren in an urban area of Sri Lanka. *The Ceylon Medical Journal. 2004;49(4):114-118*.

Wickramasinghe VP, Lamabadusuriya SP, Cleghorn GJ, Davies PSW. 2011. Defining Anthropometric cut-off levels related to metabolic risk in a group of Sri Lankan children. Ann Hum Biol 38(5):537-43.

Williams DP, Going SB, Lohman TG, Body fatness and risk for elevated blood pressure, total cholesterol and serum lipoprotein ratios in children and adolescents. *American Journal of Public Health, 1992;*82(3), 358-363.

Zimmet P, Alberti KGMM, Kaufman F, Tajima N, Silink M, Arslanian S. The metabolic syndrome in children and adolescents – an IDF consensus report. Pediatric Diabetes. 2007;8:299-306.