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MAXIMUM OXYGEN UPTAKE AND LIPID METABOLISM IN OBESE AND NON-OBESE CHINESE SINGAPOREAN BOYS AGED 13 TO 15 YEARS

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Introduction

Researchers have found that cardiovascular disease (CVD) begins in childhood and is mainly related to adverse blood lipid profiles (Klag et al., 1993; Bao et al., 1993; Porkka et al., 1994). These profiles are characterised by high levels of total cholesterol, triglyceride, low-density-lipoprotein cholesterol (LDL-C) and apoprotein B (apo B) and low levels of high-density-lipoprotein cholesterol (HDL-C) and apoprotein AI (apo AI). More recently, high levels of lipoprotein(a) (Lp(a)) and fibrinogen have been added to this list of risk factors emanating from the blood (Scanu, 1992; Ernst, 1994).

Another predisposing factor for CVD is obesity. Although not a strong independent CVD risk factor obesity has been linked to many disorders in adults which influence CVD. Such factors include hyperlipidaemia, hypertension and diabetes mellitus (Truswell, 1992). The relationship between obesity and CVD risk in children is less clear but there is some evidence that obese children have poor CVD risk factor profiles (Després et al., 1990).

A low level of cardiovascular fitness (VO_2peak) has also been reported as a CVD risk factor in children (Bell et al., 1986) though this relationship may be confounded to some extent by the relationship of VO_2peak with obesity and blood lipids. The relationship between VO_2peak and obesity depends very much on the units used to express VO_2peak ($L \cdot min^{-1}$ versus $ml \cdot kg^{-1} \cdot min^{-1}$). There is consistent evidence that when VO_2peak is expressed relative to body weight ($ml \cdot kg^{-1} \cdot min^{-1}$) it is significantly and inversely related to various obesity indices but these relationships usually disappear when VO_2peak is expressed in absolute terms ($L \cdot min^{-1}$) (Armstrong et al., 1990). Evidence of a relationship between low levels of VO_2peak and adverse lipid profiles in children is controversial with data both supporting and refuting a connection (Armstrong and Simons-Morton, 1994).

In Singapore relatively little research has been conducted to examine the relationship between cardiovascular fitness, blood lipids and obesity. As in many modernised countries, unfavourable blood lipid profiles have been observed in both obese (Ho et al., 1996) and non-obese (Stensel and Schmidt, 1995) Singaporean children. Furthermore, Nair (1996) found that on average obese children have a lower VO_2peak ($ml \cdot kg^{-1} \cdot min^{-1}$) compared to their non-obese Singaporean peers. However, no studies have examined the difference between the lipid and lipoprotein profiles of obese and non-obese Singaporean children or the interaction between VO_2peak and lipid metabolism in such groups. Moreover, although total cholesterol, HDL-C, LDL-C, and triglyceride have been studied in relation to obesity no studies have yet been published comparing apoproteins AI and B, Lp(a) or fibrinogen in obese and non-obese Singaporean children. Therefore, the purpose of the present study was firstly to determine whether blood lipids, lipoproteins, apoproteins, fibrinogen and VO_2peak differ between obese and non-obese Chinese Singaporean boys and secondly to assess the relationship between these variables in obese and non-obese Chinese Singaporean boys.

Methods

Subjects: forty-four Chinese Singaporean boys aged 13 to 15 years were recruited for this study from one secondary school in Singapore. These boys were allocated into either an obese group or a non-obese group based on the following criteria: obese group (n=22), relative weight $\geq$ 130%, adiposity > 0.5 and sum of 8 skinfolds (Σ8skf) $\geq$ 210 mm; non-obese group (n=22), relative weight < 120%, adiposity $\leq$ 0.5, Σ8skf < 180 mm. For relative weight the Ministry of Health (1993) weight for height charts were used which allow for a determination of percentage overweight or underweight based on a child's age, height, gender and ethnic group. Adiposity was determined by the ratio of fat mass to lean

body mass (LBM) and the Σ8skf was based on the total skinfold thickness (mm) calculated from eight different sites as described below.

Procedures: written informed consent was obtained from both the children and their parents before the start of the study. Moreover, approval for the study was given by the School of Physical Education (SPE) Human Ethics Committee and the Testing Branch of the Ministry of Education. Prior to the study, all subjects underwent a medical examination to ensure they were free from serious illness and were fit to participate. During the study the subjects completed the following tests: 1) body composition analysis 2) blood biochemistry and 3) cardiorespiratory fitness testing. The first two tests were done on the same day at the National University Hospital (NUH) while the third test was conducted on a separate day at the SPE.

Body composition analysis: subjects' heights were measured using a wall-mounted stadiometer (Holtain, Dyfed, Britain) to the nearest 0.1 cm. Subjects' weights were taken to the nearest 0.01 kg on an electronic weighing scale (Mettler Toledo IDL Plus, Eichfahig, Germany) in socked feet and with minimal clothing. The Quetelet Index ($kg \cdot m^{-2}$) was used as a measure of the Body Mass Index (BMI). Skinfold thicknesses on the left side of the body were measured at eight anatomical sites. A Holtain skinfold calliper (Holtain, Crymych, UK) was used and measurements were reported to the nearest 0.1 mm. Measurement was done by an experienced assistant in triplicate and the mean calculated. The eight sites were: abdomen, subscapular, suprailiac, mid-auxillary, biceps, triceps, calf and thigh. Waist/hip ratio (WHR) was derived from the circumferences at the waist and hips measured to the nearest 1 cm. Dual-energy X-ray absorptiometry (DXA) (Lunar DPX-L, software version 1.31, USA) was used to measure each subject's percentage body fat (%fat). Fat mass and LBM were also derived from the weight and %fat measurements of the subjects. The DXA scans were performed in the Orthopaedic Diagnostic Centre at the NUH.

Blood biochemistry analysis: this was performed in the Department of Laboratory Medicine at the NUH. This laboratory is accredited by the World Health Organisation. Subjects fasted for 12 hours before blood samples were taken by experienced nurses. 20 ml of venous blood was collected from which serum concentrations of triglyceride, total cholesterol, HDL-C, LDL-C, apo AI, apo B, Lp(a) and fibrinogen were determined immediately.

Cardiorespiratory fitness testing: the VO_2peak of the subjects was measured via a maximal walking treadmill (18-60, Quinton Instrument, USA) test using a modified Balke protocol. A Sensormedics metabolic cart (Sensormedics 2900Z, USA) was used to collect and analyse expired gas samples. This metabolic cart was calibrated prior to each testing session. Following calibration a half-face mask with a two-way breathing valve (2700, Hans Rudolph Inc., Kansas, USA) was fitted to each subject and connected by respiratory tubes to the metabolic cart. The subjects then warmed up for one minute by walking at 5.0 $km \cdot h^{-1}$ on a level gradient. After this they went straight into the test. The walking speed for the test was pre-selected and varied between 5.0 and 5.5 $km \cdot h^{-1}$ based on data from familiarisation tests. The initial gradient was 6% and there was a 3% increase in gradient every 3 minutes. Subjects were verbally encouraged to continue walking until exhaustion and music to each subject's liking was played to further motivate them. The test was terminated when the subjects indicated that they were unable to continue. Expired air was collected throughout the test and heart rate was recorded during the last one minute of every stage via a heart rate monitor (Polar PE 4000). Finger prick blood samples were collected two minutes after the test for determination of whole blood lactate concentration via a portable lactate analyser (Accusport: Boehringer Mannheim, Germany). The Children's Effort Rating Table (CERT) (Lamb, 1995) was used at every stage of the test to indicate each boy's rate of perceived exertion. Criteria for maximal effort included three or more of the following: a respiratory exchange ratio ≥ 1.0, a heart rate $\geq$ 195 $beat \cdot min^{-1}$, a blood lactate concentration $\geq$ 5.8 $mmol \cdot L^{-1}$ and a CERT rating ≥ 9.

Statistical analysis: these were conducted using the SPSS (Version 6.0). Non-parametric statistics were used due to the skewed nature of the subject distribution. Differences between obese and non-obese subjects were assessed using a Mann Whitney U test while Spearman Rank Order Correlation was used to examine relationships between variables. Significance was set at the $p < 0.05$ level.

Results

The age, height, weight and VO_2peak of the obese and non-obese boys are shown in Table 1. The obese group was significantly older than the non-obese group but only by four months. Height did not differ significantly between the groups but the obese group were significantly heavier than the non-obese group by 21.4 kg. The non-obese boys had a significantly higher VO_2peak than the obese boys when values were expressed in relative terms ($ml \cdot kg^{-1} \cdot min^{-1}$) but when values were expressed in absolute terms ($L \cdot min^{-1}$) there were no significant differences between the groups.

Table 1: Physical characteristics of the obese and non-obese Chinese Singaporean boys (mean ± SD).

	Obese (n=22)	Non-obese (n=22)
Age (yrs)	13.7 ± 0.5*	13.4 ± 0.6
Height (m)	1.66 ± 0.08	1.63 ± 0.06
Weight (kg)	78.2 ± 10.2*	56.8 ± 5.9
VO_2peak ($ml \cdot kg^{-1} \cdot min^{-1}$)	32.5 ± 3.5**	41.0 ± 3.6
VO_2peak ($L \cdot min^{-1}$)	2.54 ± 0.34	2.33 ± 0.37

Obese significantly different from non-obese: *p<0.05; **p<0.01

Table 2 shows the body composition measures of the two groups. Values of the obese boys were significantly higher than those of the non-obese boys for all variables except LBM. Of particular note were the differences between obese and non-obese boys respectively for %fat: 41.8 versus 25.7%, BMI: 28.4 versus 21.5 $kg \cdot m^{-2}$ and fat mass: 31.0 versus 13.7 kg.

Table 2: Body composition variables for the obese and non-obese Chinese Singaporean boys (mean ± SD).

	Obese (n=22)	Non-obese (n=22)
Relative weight (%)	139.9 ± 11.8**	106.4 ± 6.0
BMI ($kg \cdot m^{-2}$)	28.4 ± 2.3**	21.5 ± 1.3
%fat	41.8 ± 3.9**	25.7 ± 5.3
Σ8skf (mm)	240.5 ± 17.3**	143.7 ± 24.2
WHR	0.90 ± 0.04**	0.84 ± 0.04
Fat mass (kg)	31.0 ± 5.4**	13.7 ± 3.0
LBM (kg)	43.0 ± 6.0	39.9 ± 5.6
Adiposity (fat mass:LBM)	0.73 ± 0.12**	0.35 ± 0.09

Obese significantly different from non-obese: **p<0.01

Table 3 displays the lipid, lipoprotein, apoprotein and fibrinogen profiles of the two groups of boys. Only the triglyceride and fibrinogen values differed significantly between groups. In both cases the obese boys had higher values than the non-obese boys: triglyceride 1.6 versus 1.2 $mmol \cdot L^{-1}$, fibrinogen 3.9 versus 3.3 $g \cdot L^{-1}$ for obese and non-obese boys respectively.

Table 3: Blood biochemistry variables for obese and non-obese Chinese Singaporean boys (mean ± SD).

	Obese (n=22)	Non-obese (n=22)
Triglyceride ($mmol \cdot L^{-1}$)	1.6 ± 0.7*	1.2 ± 0.6
Total cholesterol ($mmol \cdot L^{-1}$)	4.4 ± 0.6	4.2 ± 1.0
HDL-C ($mmol \cdot L^{-1}$)	1.0 ± 0.2	1.1 ± 0.2
LDL-C ($mmol \cdot L^{-1}$)	2.6 ± 0.5	2.6 ± 0.8
apo AI ($mg \cdot dL^{-1}$)	118.3 ± 13.4	116.8 ± 17.4
apo B ($mg \cdot dL^{-1}$)	88.8 ± 20.8	77.8 ± 21.8
Lp(a) ($mg \cdot dL^{-1}$)	16.4 ± 14.7	18.6 ± 16.6
Fibrinogen ($g \cdot L^{-1}$)	3.9 ± 0.6**	3.3 ± 0.8

Obese significantly different from non-obese: *p<0.05; **p<0.01

Significant negative correlations were observed between VO_2peak expressed in relative terms ($ml \cdot kg^{-1} \cdot min^{-1}$) and most of the body composition measures when the two groups of boys were pooled together (Table 4). The strongest relationship here was between VO_2peak and fat mass (rho = -0.84, p<0.01). Only LBM was not significantly correlated with VO_2peak expressed in relative terms. When VO_2peak was expressed in absolute terms ($L \cdot min^{-1}$) it correlated significantly with all body composition measures except %fat, WHR and adiposity. LBM, which was not significantly correlated to VO_2peak expressed in relative terms, was highly correlated (rho = 0.78, p<0.01) with absolute VO_2peak.

Table 4: Spearman Rank Order correlations between body composition and VO_2peak for the pooled values (n=44) of all boys in the study.

	Fat mass	LBM	Σ8skf	RW	BMI	%fat	WHR	Adiposity
VO_2peak ($ml \cdot kg^{-1} \cdot min^{-1}$)	-0.84**	-0.15	-0.73**	-0.75**	-0.75**	-0.80**	-0.50**	-0.80**
VO_2peak ($L \cdot min^{-1}$)	0.33*	0.78**	0.32*	0.37*	0.48**	0.18	0.17	0.18

RW = relative weight. Significant correlations: *p<0.05; **p<0.01

Correlations between blood biochemistry measures and VO_2peak expressed in absolute and relative units are shown in Table 5. Triglyceride and fibrinogen both correlated significantly with VO_2peak expressed in relative terms (rho = -0.36 and -0.49 respectively). None of the other lipids, lipoproteins or apoproteins correlated significantly with relative VO_2peak. When expressed in absolute terms VO_2peak did not correlate significantly with any of the blood biochemistry variables.

Table 5: Spearman Rank Order correlations between VO_2peak and blood biochemistry variables for the pooled values (n=44) of all boys in the study.

	TG	TC	HDL-C	LDL-C	apo AI	apo B	Lp(a)	FIB
VO_2peak ($ml \cdot kg^{-1} \cdot min^{-1}$)	-0.36*	-0.17	-0.15	-0.08	-0.02	-0.25	-0.01	-0.49**
VO_2peak ($L \cdot min^{-1}$)	-0.08	-0.21	-0.24	-0.16	-0.10	-0.04	-0.09	0.06

TG = triglyceride, TC = total cholesterol, FIB = fibrinogen. Significant correlations: *p<0.05; **p<0.01

Table 6 shows Spearman Rank Order correlations between body composition and blood biochemistry measures for the 44 boys. Triglyceride and fibrinogen were significantly correlated with many of the body composition measures though correlations were only in the low to moderate range. Aside from triglyceride and fibrinogen none of the remaining blood biochemistry variables were significantly correlated to any of the body composition indices.

Table 6: Spearman Rank Order correlations between body composition and blood biochemistry variables for the pooled values (n=44) of all boys in the study.

	Fat mass	LBM	Σ8skf	RW	BMI	%fat	WHR	Adiposity
Triglyceride	0.33*	-0.07	0.36*	0.33*	0.28	0.38*	0.31*	0.38*
Total cholesterol	0.11	-0.21	0.08	0.12	0.06	0.16	0.12	0.16
HDL-C	-0.19	-0.29	-0.11	-0.13	-0.16	-0.12	-0.82	-0.12
LDL-C	0.05	-0.16	-0.01	0.03	-0.01	0.09	0.01	0.09
apo AI	0.04	-0.13	0.10	0.17	0.12	0.06	0.07	0.06
apo B	0.24	-0.03	0.23	0.23	0.20	0.25	0.24	0.25
Lp(a)	-0.04	-0.08	-0.05	-0.10	-0.10	0.01	-0.19	0.01
Fibrinogen	0.56**	0.02	0.51**	0.47**	0.47**	0.58**	0.28	0.58**

RW = relative weight. Significant correlations: *p<0.05; **p<0.01

Discussion

The use of adiposity (fat mass/LBM) and Σ8skf in conjunction with relative weight ensured that the two groups of boys in this study were distinctly different in terms of body composition. The ratio of fat mass to LBM was taken as a measure of overall adiposity to ensure that fat mass was expressed in relation to LBM as suggested by Goran and colleagues (1995). The Σ8skf is another good indicator of obesity as the majority of fat in the body is subcutaneous. Thus, the obese group in the present study were 21 kg heavier than the non-obese group with 17 kg more of fat despite the fact there were no significant differences between the two groups for either height or LBM (Tables 1 and 2).

VO_2peak (Table 1) was significantly higher in the non-obese boys compared to the obese boys when expressed in relative terms (41.0 versus 32.5 $ml \cdot kg^{-1} \cdot min^{-1}$ respectively). Indeed, 16 (73%) of the obese boys had VO_2peak values $\leq$35.0 $ml \cdot kg^{-1} \cdot min^{-1}$ which would put them at increased risk of CVD according to Bell and colleagues (1986). Only 1 (5%) of the non-obese boys fell into this high risk category. This is predictable since body weight is used as the denominator for the relative VO_2peak measurement and a higher denominator will result in a lower VO_2peak value. This is confirmed by the

fact that relative VO_2peak and fat mass were highly, negatively correlated (rho = -0.84) for the pooled values (n=44) indicating that fat mass is probably the most important determinant of VO_2peak when a group is heterogeneous in terms of body composition. However, when VO_2peak was expressed in absolute terms there were no significant differences between the two groups (2.33 versus 2.54 $L \cdot min^{-1}$ for the non-obese and obese boys respectively). In this case the most important determinant of VO_2peak ($L \cdot min^{-1}$) appears to be LBM because the correlation between LBM and absolute VO_2peak was 0.78.

Based on the preceding discussion it is clear that obese boys are bound to have poorer cardiovascular fitness than non-obese boys when VO_2peak is expressed relative to body weight. Although this may seem unfair it would undoubtedly reflect a poorer endurance capacity in weight bearing exercise which would not be indicated by expressing VO_2peak in absolute terms. An alternative method to both of these would be the use of a scaling factor such as $ml \cdot kg^{-0.67} \cdot min^{-1}$ as suggested by Welsman and colleagues (1996) and perhaps this will gain acceptance in the future.

Of the blood biochemistry variables measured in this study, only triglyceride and fibrinogen differed significantly between the obese and non-obese boys (Table 3). This is slightly surprising since obesity is often associated with hyperlipidaemia in adults (Goldstein et al., 1973). Less information is available regarding the relationship between obesity and lipids in children but the Bogalusa Heart Study has shown that CVD risk factors (including blood lipids) tend to cluster in obese American children (Smoak et al., 1987). It is possible that the two groups studied here were not distinct enough in terms of body composition for differences to emerge. This is an unlikely explanation, however, because body fat was 41.8% in the obese group and only 25.7% in the non-obese group. Moreover, the obese boys were carrying 17 kg more fat than the non-obese boys despite being of similar height.

Both groups of boys in the present study exhibited higher values for triglyceride, total cholesterol and LDL-C, and lower values for HDL-C, than the healthy, non-obese boys of similar age in America studied by Tamir and co-workers (1981). This provides some support for an obesity effect since even the 'non-obese' boys in the present study had a mean body fat percentage of 25.5 which is considered borderline obesity. Moreover, Ho and colleagues (1996) studied a group of Chinese Singaporean boys (mean age 13.0 years) who were more obese than the obese boys in the present study (relative weight = 164.2% versus 139.9%) and they found higher values still for total cholesterol and LDL-C and lower values for HDL-C than those found in the present study (total cholesterol = 5.0 versus 4.4 $mmol \cdot L^{-1}$, LDL-C = 3.6 versus 2.6 $mmol \cdot L^{-1}$, HDL-C = 0.7 versus 1.0 $mmol \cdot L^{-1}$ for the subjects of Ho and colleagues (1996) versus the subjects in the present study respectively).

An examination of the relationship between various blood biochemistry and body composition measures revealed that when the obese and non-obese boys were pooled together only triglyceride and fibrinogen correlated significantly with any of the body composition measures (Table 6). For both triglyceride and fibrinogen the highest correlation was with percentage body fat (rho = 0.38 and 0.58 respectively). This appears to confirm the above finding that for these thirteen year old adolescents, obesity is associated with high levels of triglyceride and fibrinogen but is not adversely related to any of the other lipids, lipoproteins or apoproteins measured in this study. Nevertheless, this is a significant finding in itself since both triglyceride and fibrinogen are involved in the atherosclerotic process and it is possible that these are merely the first two variables to change as children become obese and that continued obesity in these adolescents will result in undesirable changes in other blood lipid, lipoprotein and apoprotein variables.

When examining the relationships between fitness (VO_2peak) and blood biochemistry variables a similar picture emerged as for obesity and the blood biochemistry variables i.e. the only significant correlations involved triglyceride and fibrinogen (Table 5). In fact, none of the blood biochemistry variables correlated significantly with absolute VO_2peak but relative VO_2peak was inversely correlated to both triglyceride (rho = -0.36) and fibrinogen (rho = -0.49). These findings would suggest that fitness has a beneficial effect on triglyceride and fibrinogen. There are plausible explanations for both of these findings. Podl and colleagues (1994), for example, have shown that endurance trained subjects (with high maximum oxygen uptakes) exhibit high lipoprotein lipase activities which enhance their triglyceride clearance rates and help to keep their blood triglyceride levels low. Moreover, studies in adults have shown that chronic exercise training is related to low plasma fibrinogen levels with haemodilution being cited as the possible mechanism of interaction here (El-Sayed, 1996). It seems

more likely, however, that the relationships just described are confounded by the influence of fat mass on relative VO_2peak. In other words fat mass (or %fat) is the major determinant of relative VO_2peak as well as being the major determinant of triglyceride and fibrinogen (as shown by the correlations in Tables 4 and 6). If this is the case then the relationship of VO_2peak with triglyceride and fibrinogen is merely coincidental. This is supported by the fact that absolute VO_2peak was not significantly related to either triglyceride or fibrinogen.

Conclusion

The major finding in this study is that the obese Chinese Singaporean boys had significantly higher levels of triglyceride and fibrinogen than their non-obese counterparts. These differences indicate an elevated CVD risk in the obese boys compared to the non-obese boys. It would be wrong to overemphasise this last point because the other lipids, lipoproteins and apoproteins measured in this study did not differ between groups and triglyceride and fibrinogen are not the most potent of CVD risk factors. It is plausible, however, that triglyceride and fibrinogen are merely the first variables to be adversely affected by obesity and that, given time, other lipids, lipoproteins and apoproteins will follow suit. The obese boys in this study also exhibited significantly lower VO_2peak values in relative terms than their non-obese counterparts. According to Bell and colleagues (1986) this alone would indicate elevated CVD risk. Caution is required in interpreting these findings, however, because the use of relative VO_2peak in obese subjects has been questioned and absolute VO_2peak did not differ significantly between the obese and non-obese boys. Future research should focus on longitudinal study of similar groups of subjects to determine if the undesirable CVD profiles observed in the adolescents examined here become exacerbated over time with continued obesity.

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