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Prevalence and trend of dyslipidaemia from 1996 to 2006 among normal and overweight adolescents in Taiwan

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ABSTRACT

Objectives: To evaluate the trend of dyslipidaemia from 1996 to 2006 and examine its relationship with weight status among adolescents in Taiwan.

Design: 2 cross-sectional surveys were conducted in 1996 and 2006.

Setting: The junior high schools in Taipei.

Participants: After multistage sampling, total of 1500 and 1283 junior high school students were chosen in 1996 and 2006. After excluding missing data, a total of 1353 (676 boys and 677 girls) and 1203 (585 boys and 618 girls) children were included in the final analyses in 1996 and 2006.

Outcome measures: Anthropometric measures as body height and weight were measured, and body mass index (BMI) was calculated. Blood lipid profiles as total cholesterol, triglyceride, high-density lipoprotein cholesterol (HDL-C) and low-density lipoprotein cholesterol were measured.

Results: From 1996 to 2006, the prevalence of dyslipidaemia and hypercholesterolaemia significantly increased from 13% (95% CI 11.3% to 15.0%) to 22.3% (95% CI 20.0% to 24.7%) and 6.2% (95% CI 5.0% to 7.6%) to 13.8% (95% CI 11.9% to 15.9%), respectively. The prevalence of hypertriglyceridaemia and low HDL-C dyslipidaemia increased from 3% (95% CI 1.8% to 4.5%) to 4.3% (95% CI 2.8% to 6.2%) and 6.5% (95% CI 4.8% to 8.6%) to 11.6% (95% CI 9.1% to 14.5%), with significance seen only in boys. When compared with normal weight participants, overweight boys and girls faced a 2-fold and 1.6-fold increased risk of dyslipidaemia, respectively, in the 2006 study. The increased risk of low HDL-C dyslipidaemia for overweight participants was 2.6-fold and 7.2-fold in boys and girls, respectively. In 2006, each unit increment of BMI was associated with 28%, 13% and 13% risk of hypertriglyceridaemia, low HDL-C and dyslipidaemia for boys, and 25% risk of low HDL-C dyslipidaemia in girls.

Conclusions: The prevalence of dyslipidaemia had increased significantly for boys and girls in normal weight and overweight adolescents. Early screening of dyslipidaemia and weight intervention programmes in adolescents will be the key to prevent dyslipidaemia and cardiovascular-related comorbidities.

Strengths and limitations of this study

- Repeat cross-sectional survey conducted in 1996 and 2006 with sufficient sample size to evaluate the trend of dyslipidaemia among adolescents.
- Demonstrates the detailed characteristics of lipid profiles (including total cholesterol, triglyceride, high-density lipoprotein cholesterol and low-density lipoprotein cholesterol) among adolescents.
- Provide information regarding the trend and prevalence of different definition of dyslipidaemia among normal and overweight adolescents.
- Analyses different models for adjusting the potential confounders such as age, gender, cigarette smoking, alcohol intake and puberty status and year trend.
- Dietary and physical activity information collected and analysed were inappropriate due to limitations of instrument.

INTRODUCTION

Cardiovascular disease (CVD) is the leading cause of death worldwide and accounts for 30% of all global deaths.[1] The WHO predicts that, by 2030, CVD will account for 23.3 million deaths compared with the 17.3 million deaths seen in 2008.[1]

CVD is a group of disorders which affect the heart and/or the blood vessels. Disorders include coronary heart disease, cerebrovascular disease, peripheral arterial disease, rheumatic heart disease, congenital heart disease, deep vein thrombosis, pulmonary embolisms, etc.[1] In addition to age and gender, unhealthy diets, physical inactivity, hyperglycaemia, cigarette smoking, dyslipidaemia, hypertension, type 2 diabetes and obesity have been identified as risk factors for the prediction of development of CVD.[1–3]

Childhood obesity has also been identified as one of the most important risk factors of developing cardiometabolic diseases such as dyslipidaemia, insulin resistance and hypertension.[4–7] The trends of obesity and

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dyslipidaemia have been studied extensively in Western societies; however, there is a lack of data pertaining to adiposity and abnormal lipid profiles in the Taiwanese population.[8] The research into the relationship between children with abnormal blood lipid profiles and CVD is important to mitigating the problem of childhood obesity.

In Taiwan, the prevalence of obesity also continues to increase among adults and children, which may be attributed to the steadily increasing availability of a high-fat, high-calorie diet as well as a more sedentary and physically inactive lifestyle.[9–12] In recent 20 years, there was also an increase in prevalence rate of overweight and obesity among Taiwanese adolescents (12–15 years).[10 13] The trend of overweight has almost tripled over two decades, from 3% to 12% from the years 1970–1988.[13 14]

The purpose of this study was to evaluate the recent trend of dyslipidaemia and its relation to anthropometric and biochemical measurements in order to predict the future prevalence rate of CVD among adolescents in Taiwan.

MATERIALS AND METHODS

Study population and design

The Taipei Children Heart Studies were a series of epidemiological surveys conducted during the past two decades which investigated CVD risk factors among school children living in Taipei, Taiwan.[15] In 1996 and 2006, two cross-sectional surveys were conducted in Taipei among junior high school students in order to ascertain a representative distribution of demographic, lifestyle and biochemical characteristics and CVD risk factors. During 1996, 101 000 junior high school students were enrolled in 47 large schools (≥40 classes per school) and 28 000 students in 38 small schools (<40 classes per school). After multistage sampling, random selection of seven large schools and three small schools, with six classes sampled per school, a total of 1500 junior high school students were chosen for this epidemiological survey in 1996. The same techniques were used for the multistage sampling method conducted in 2006 and a total of 1283 students were selected. After factoring in study power and excluding missing data, a total of 1353 (676 boys and 677 girls) and 1203 (585 boys and 618 girls) children were included in the final analyses in 1996 and 2006.

All participating children completed a structured questionnaire detailing their gender, age, puberty development and lifestyle characteristics, such as cigarette smoking and alcohol consumption. The questionnaires were submitted to an expert panel with each question tested for test–retest reliability and validity. Informed consent was obtained from the parents and children.

Anthropometric, blood pressure and lipid measurements

Body weight (BW) was measured to an accuracy of 0.1 kg using a standard beam balance scale for participants in barefoot and wearing light indoor clothing. Body height was recorded to the nearest 0.5 cm using a stadiometer. Waist circumference (WC) was measured to the nearest 0.1 cm at the midpoint between the inferior margin of the last rib and the iliac crest. Body mass index (BMI) was calculated using BW (kg) divided by the square of their height (m^2).

For the systolic (SBP) and diastolic blood pressure (DBP) measurements, participants were asked to rest for 10 min in a sitting position before their BP was taken on their right arm using appropriate cuff sizes. The first and fifth Korotkoff sounds were recorded for the SBP and DBP, respectively. The BP was measured again after a 5 min resting period and the average was used in the analyses. In between the two BP measures, heart rate was measured for 1 min.

A 12 h fasting blood sample was taken from students who maintained their usual dietary pattern within the past 3 days. The plasma glucose concentrations were analysed immediately after blood sampling and other assays were performed within a 2-week period of the sampling. Plasma glucose levels were measured using a standard method, serum total cholesterol (TC) using an esterase oxidase method, triacylglycerol using an enzymatic procedure and high-density lipoprotein (HDL) cholesterol using an enzymatic method with magnesium precipitation with the Synchron CX5 analyzer (Beckman Instruments, Palo Alto, California, USA).[16–20] Since all samples were collected after a 12 h fast and no triacylglycerol concentrations exceeded 4.52 mmol/L (400 mg/dL), we used Friedewald's formula to calculate the low-density lipoprotein (LDL) cholesterol: LDL cholesterol = (TC − HDL cholesterol) − (triacylglycerol/5).[21] We also determined the ratio of total to HDL cholesterol (total: HDL cholesterol) for statistical purposes.

Definition of overweight, obesity and abnormal lipid profiles

The operational definition of overweight and obesity is determined by applying gender-specific and age-specific percentile cut-off points in a reference population (generally the 85th centile for overweight and 95th centile for obesity). Our study defined overweight and obesity as ≥85th centile value and ≥the95th centile value of BMI, respectively, using gender-specific and age-specific criteria from childhood obesity expert panel of the Department of Health (DOH), Taiwan.[22]

The cut-offs for children for the abnormal lipid profiles were determined using guidelines from the American Heart Association (AHA).[3] Hypercholesterolaemia and hypertriglyceridaemia were taken as cholesterol greater than 200 mg/dL and serum triglyceride (TG) greater than 150 mg/dL, respectively. Low HDL dyslipidaemia was taken as serum HDL-C lower than 35 mg/dL, and dyslipidaemia was taken as one or more of the above listed abnormal lipid profiles found in the participants.

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Statistical analysis

Continuous variables, anthropometric characteristics and lipid profiles with gender specification were described by sample means and SD. Age-adjusted means and SE were estimated using the general linear model (GLM). Categorical variables were expressed through frequency using percentages. To determine whether weight status was a predictor of dyslipidaemia, multivariate regression models were used to assess the association between dyslipidaemia and its subtypes with weight status. A two-tailed p value less than 0.05 was considered statistically significant. All statistical analyses were conducted by the statistical package SAS V.9.0 (SAS Institute Inc, Cary, North Carolina, USA).

RESULTS

In the 1996 survey, a total of 1353 children (676 boys and 677 girls) with a mean age of 13.0 (range 12–14-year-olds) were included. After adjusting for age, mean (±SE) TC was 151.6±1.1 and 161.5±1.1 mg/dL, TGs was 70.4±1.3 and 77.2±1.3 mg/dL, HDL-C was 53.7±0.5 and 55.1 ±0.5 mg/dL and LDL-C was 93.9±1.1 and 102.1±1.1 for boys and girls, respectively. In the 2006 survey, a total of 1203 children (585 boys and 618 girls) were included. After adjusting for age, mean (±SE) TC was 164.1±1.2 and 174.5±1.2 mg/dL, TGs was 70.9±1.4 and 72.1 ±1.4 mg/dL, HDL-C was 47.3±0.5 and 51.5±0.5 mg/dL and LDL-C was 93.0±1.1 and 97.0±1.1 for boys and girls, respectively. The anthropometric data and lifestyle characteristics for boys and girls in the 1996 and 2006 studies are presented in table 1. Overall, the age-adjusted mean BW, BMI and WC for boys increased from 1996 to 2006 (all p<0.05). However, the weight and BMI for girls slightly decreased in that same time period.

Table 2 shows the age-adjusted prevalence and secular trends of hypercholesterolaemia, hypertriglyceridaemia, low HDL dyslipidaemia and general dyslipidaemia

Table 1 General characteristics among study children between 1996 and 2006 in Taiwan

	1996				2006				
Boys	Mean±SE* (n=676)	85th	90th	95th	Mean±SE* (n=585)	85th	90th	95th	p Value†
Age (years)	12.9±0.03	NA	NA	NA	12.9±0.03	NA	NA	NA	
Height (cm)	161.9±0.3	170.0	171.5	174.5	163.5±0.3	172.5	174.0	176.7	0.230
Weight (kg)	55.5±0.4	67.5	71.5	78.0	58.0±0.5	73.0	76.8	82.5	0.006
BMI (kg/m^2)	21.1±0.1	25.2	26.5	28.7	21.6±0.2	26.4	27.3	29.3	0.013
Waist (cm)	68.3±0.3	77.2	80.8	86.6	73.5±0.4	85.0	88.0	92.0	<0.001
SBP (mm Hg)	113.9±0.5	127.0	130.5	135.0	117.8±0.5	131.0	134.5	141.5	0.001
DBP (mm Hg)	67.6±0.4	77.0	80.0	83.0	69.0±0.4	79.0	81.5	86.5	0.093
Chol (mg/dL)	151.6±1.1	179.0	186.0	200.0	164.1±1.2	192.0	202.0	213.0	<0.001
TGs (mg/dL)	70.4±1.3	99.0	113.0	134.0	70.9±1.4	101.0	118.0	145.0	0.464
HDL (mg/dL)	53.7±0.5	67.0	70.0	77.0	47.3±0.5	59.0	62.0	66.0	<0.001
Glucose (mg/dL)	93.4±0.3	101.0	103.0	106.0	93.6±0.3	100.0	102.0	105.0	0.556
LDL	93.9±1.1	118.56	126.83	140.50	93.00±1.08	117.00	126.00	140.00	0.711
Non-HDL	97.9±1.1	123.00	131.00	145.00	116.80±1.13	141.00	150.00	164.00	<0.001
Chol/HDL	2.97±0.03	3.66	4.05	4.63	3.61±0.03	4.49	4.80	5.25	<0.001
TGs/HDL	1.44±0.04	2.15	2.44	3.23	1.66±0.04	2.49	2.94	4.03	0.002
Girls	(n=677)				(n=618)				
Age (years)	13.0±0.03	NA	NA	NA	12.9±0.03	NA	NA	NA	
Height (cm)	156.3±0.3	162.0	163.5	165.0	156.9±0.3	162.5	163.5	166.0	0.379
Weight (kg)	50.8±0.4	59.0	62.5	69.5	50.6±0.5	59.6	64.1	69.4	0.027
BMI (kg/m^2)	20.7±0.1	24.0	25.2	27.4	20.5±0.2	24.0	25.2	27.6	0.005
Waist (cm)	63.2±0.3	68.6	72.3	76.9	69.2±0.4	77.5	80.5	85.0	<0.001
SBP (mm Hg)	104.4±0.5	117.0	120.0	126.0	111.2±0.5	124.0	127.5	133.0	<0.001
DBP (mm Hg)	67.7±0.4	77.5	80.0	84.0	69.7±0.4	79.0	81.5	87.0	<0.001
Chol (mg/dL)	161.5±1.1	187.0	195.0	209.0	174.5±1.2	204.0	212.0	227.0	<0.001
TGs (mg/dL)	77.2±1.3	107.0	118.0	140.0	72.1±1.4	102.0	117.0	131.0	0.003
HDL (mg/dL)	55.1±0.5	68.0	71.0	76.0	51.5±0.5	63.0	66.0	70.0	<0.001
Glucose (mg/dL)	91.6±0.3	99.0	101.0	104.0	91.6±0.3	99.0	101.0	103.0	0.757
LDL	102.1±1.1	129.17	134.78	145.78	97.02±1.05	125.00	131.00	143.00	<0.001
Non-HDL	106.4±1.1	133.00	140.00	151.00	122.95±1.10	148.00	159.00	172.00	<0.001
Chol/HDL	3.04±0.03	3.85	4.00	4.35	3.49±0.03	4.14	4.42	4.85	<0.001
TGs/HDL	1.51±0.04	2.21	2.56	3.02	1.51±0.04	2.28	2.59	3.28	0.739

*Age-adjusted mean±SE.
†p Value when compared with the same gender group for 1996 and 2006 using GLM after adjusting for age, cigarette smoking, alcohol drinking and puberty status.
BMI, body mass index; Chol, total cholesterol; DBP, diastolic blood pressure; GLM, general linear model; HDL, high-density lipoprotein-cholesterol; LDL, low-density lipoprotein; SBP, systolic blood pressure; TGs, triglycerides.

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Table 2 Prevalence and secular trends of abnormal lipid profiles among children between year 1996 and 2006 in Taiwan

	1996 (n=1353)		2006 (n=1203)		
	N	Per cent (95% CI)†	N	Per cent (95% CI)†	p Value*
Hypercholesterolaemia‡	84	6.21 (4.98 to 7.63)	166	13.8 (11.90 to 15.88)	<0.001
Boys	33	4.88 (3.38 to 6.79)	62	10.6 (8.22 to 13.38)	<0.001
Girls	51	7.53 (5.66 to 9.79)	104	16.83 (13.96 to 20.02)	<0.001
Hypertriglyceridaemia§	42	3.10 (2.25 to 4.17)	39	3.24 (2.32 to 4.44)	0.843
Boys	20	2.96 (1.82 to 4.53)	25	4.27 (2.78 to 6.24)	0.209
Girls	22	3.25 (2.05 to 4.88)	14	2.27 (1.24 to 3.77)	0.282
Low HDL dyslipidaemia†	63	4.66 (3.60 to 5.92)	88	7.32 (5.91 to 8.93)	0.004
Boys	44	6.51 (4.77 to 8.64)	68	11.62 (9.14 to 14.50)	0.002
Girls	19	2.81 (1.70 to 4.35)	20	3.24 (1.99 to 4.95)	0.651
Dyslipidaemia¶	176	13.01 (11.26 to 14.92)	268	22.28 (19.95 to 24.74)	<0.001
Boys	91	13.46 (10.98 to 16.27)	138	23.59 (20.20 to 27.24)	<0.001
Girls	85	12.56 (10.15 to 15.29)	130	21.04 (17.89 to 24.46)	<0.001

*p Value when compared with 1996.
†Low HDL dyslipidaemia is taken as serum HDL-C of age-specific, gender-specific and height-specific strata.
‡Hypercholesterolaemia is taken as cholesterol greater than or equal to the 90th centile of age-specific, gender-specific and height-specific strata.
§Hypertriglyceridaemia is taken as serum triglyceride greater than or equal to the 95th centile of age-specific, gender-specific and height-specific strata.
¶Dyslipidaemia is taken as serum cholesterol, TGs, HDL-C of age-specific, gender-specific and height-specific strata.
HDL, high-density lipoprotein; HDL-C, HDL-cholesterol; TGs, triglycerides.

among children in Taiwan in 1996 and 2006. For both genders, the prevalence of hypercholesterolaemia and general dyslipidaemia increased from 1996 to 2006. The prevalence of hypertriglyceridaemia and low HDL dyslipidaemia also increased, but only in boys. The prevalence of dyslipidaemia and hypercholesterolaemia increased from 13% (95% CI, 11.3% to 15.0%) to 22.3% (95% CI 20.0% to 24.7%) and 6.2% (95% CI 5.0% to 7.6%) to 13.8% (95% CI 11.9% to 15.9%), in boys and girls, respectively. Hypertriglyceridaemia and low HDL dyslipidaemia increased from 3% (95% CI 1.8% to 4.5%) to 4.3% (95% CI 2.8% to 6.2%) and 6.5% (95% CI 4.8% to 8.6%) to 11.6% (95% CI 9.1% to 14.5%), in boys and girls, respectively, with significance seen only in boys (see figure 1).

Table 3 demonstrates the age-adjusted prevalence of hypercholesterolaemia, hypertriglyceridaemia, low HDL dyslipidaemia and general dyslipidaemia separated by weight status in 1996 and 2006. The prevalence of all types of dyslipidaemia increased from 1996 to 2006 in

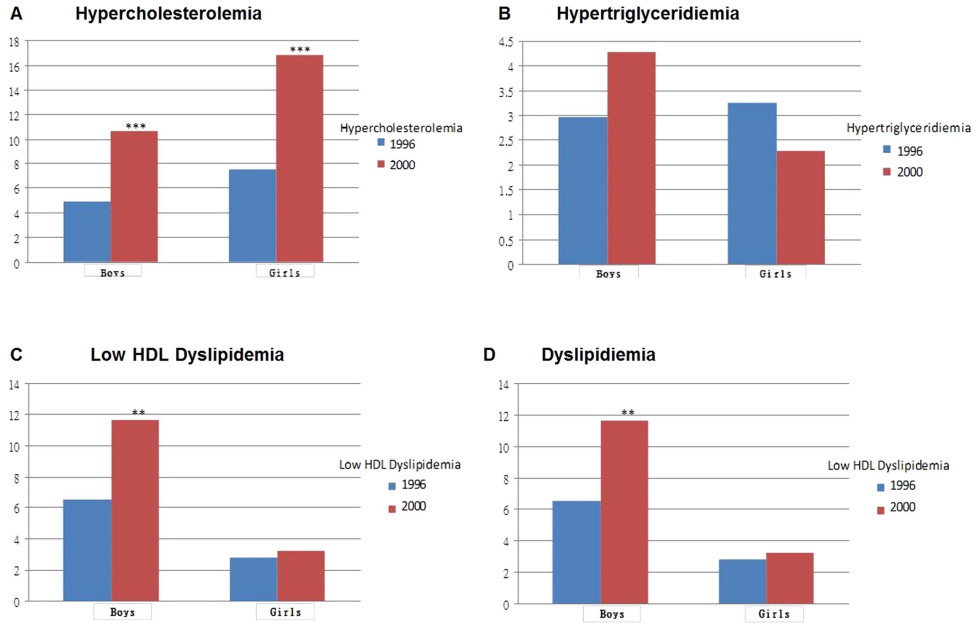

Figure 1 Prevalence and secular trends of abnormal lipid profiles among children between year 1996 and 2006 in Taiwan. HDL, high-density lipoprotein.

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Table 3 Prevalence and secular trends of abnormal blood lipid profiles among different weight status children between 1996 and 2006 in Taiwan

	1996				2006		
	N	Per cent*‡‡	p Value†	p Value‡	N	Per cent*‡‡	p Value‡
Hypercholesterolaemia§							
Boys							
Normal weight	22	4.76	0.006	0.832	35	9.67	0.352
Overweight¶	11	5.14	0.010		27	12.11	
Girls							
Normal weight	39	7.62	<0.001	0.884	76	16.27	0.517
Overweight¶	12	7.27	0.003		28	18.54	
Hypertriglyceridaemia**							
Boys							
Normal weight	2	0.43	0.468	<0.001	3	0.83	<0.001
Overweight¶	18	8.41	0.598		22	9.87	
Girls							
Normal weight	16	3.13	0.093	0.747	7	1.50	0.024
Overweight¶	6	3.64	0.655		7	4.64	
Low HDL-C dyslipidaemia††							
Boys							
Normal weight	18	3.90	0.037	<0.001	26	7.18	<0.001
Overweight¶	26	12.15	0.054		42	18.83	
Girls							
Normal weight	10	1.95	0.410	0.018	6	1.28	<0.001
Overweight¶	9	5.45	0.192		14	9.27	
Dyslipidaemia*							
Boys							
Normal weight	42	9.09	0.001	<0.001	62	17.13	<0.001
Overweight¶	49	22.90	0.010		76	34.08	
Girls							
Normal weight	61	11.91	0.005	0.375	86	18.42	0.005
Overweight¶	24	14.55	0.002		44	29.14	

*Dyslipidaemia is taken as serum cholesterol, TGs, HDL-C of age-specific, gender-specific and height-specific strata.
†p Value when compared with 2006.
‡p Value when compared with overweight (after Bonferroni correction: α level=0.05/8=0.00625).
§Hypercholesterolaemia is taken as cholesterol greater than or equal to the 90th centile of age-specific, gender-specific and height-specific strata.
¶Overweight (include obesity) is defined as the overweight and obese status criteria of children in Taiwan.
**Hypertriglyceridaemia is taken as serum triglyceride greater than or equal to the 95th centile of age-specific, gender-specific and height-specific strata.
††Low HDL dyslipidaemia is taken as serum HDL-C of age-specific, gender-specific and height-specific strata.
‡‡Age-adjusted prevalence.
HDL, high-density lipoprotein; HDL-C, HDL-cholesterol; TGs, triglycerides.

both sexes and weight statuses, except for hypertriglyceridaemia and low HDL-C dyslipidaemia for normal weight girls. When compared with normal weight participants, overweight boys and girls faced a 2-fold and 1.6-fold increased risk of dyslipidaemia, respectively, in the 2006 study. For hypercholesterolaemia and hypertriglyceridaemia, overweight boys had 1.3-fold and 12-fold increased risk, respectively, compared with normal weight boys. The increased risk of low HDL-C dyslipidaemia for overweight participants was 2.6-fold and 7.2-fold in boys and girls, respectively.

Table 4 presents the logistic regression analysis of year trend, BMI and WC on hypercholesterolaemia, hypertriglyceridaemia, low HDL dyslipidaemia and general dyslipidaemia with gender specification after combined 1996 and 2006 data. In model 1, we found that year 2006 had a higher OR for hypercholesterolaemia, low HDL-C dyslipidaemia and dyslipidaemia (ORs was 2.310, 1.889 and 1.985, respectively) when compared with year 1996. Furthermore, each unit increment of BMI was associated with 28%, 14% and 14% increasing risk of hypertriglyceridaemia, low HDL-C dyslipidaemia and dyslipidaemia for boys, and 20% increasing risk of low HDL-C dyslipidaemia for girls. Each centimetre increase in WC was associated with 9% increased risk of low HDL dyslipidaemia in girls. Similar results were seen in model 2; increment of BMI and WC were as associated with abnormal blood lipid profiles after adjusting for age, cigarette smoking, alcohol consumption, puberty status and time trend.

DISCUSSION

The present study represents the analysis of secular trends in dyslipidaemia in Taiwanese children from 1996

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Table 4 Logistic regression analyses of BMI and WC on abnormal blood lipid profiles among children with gender specification in Taiwan (combined 1996 and 2006 data)

	Model 1		Model 2	
	OR	95% CI	OR	95% CI
Hypercholesterolaemia*				
Boys				
Year 2006 vs1996	2.310	1.491 to 3.579	–	–
BMI	1.044	0.994 to 1.096	1.039	0.988 to 1.092
WC	1.025	1.006 to 1.045	1.017	0.996 to 1.038
Girls				
Year 2006 vs1996	2.484	1.742 to 3.541	–	–
BMI	1.030	0.984 to 1.078	1.027	0.980 to 1.077
WC	1.032	1.013 to 1.051	1.015	0.994 to 1.036
Hypertriglyceridaemia†				
Boys				
Year 2006 vs1996	1.464	0.805 to 2.665	–	–
BMI	1.284	1.205 to 1.369	1.299	1.217 to 1.388
WC	1.102	1.074 to 1.131	1.109	1.079 to 1.139
Girls				
Year 2006 vs1996	0.690	0.350 to 1.361	–	–
BMI	1.078	0.994 to 1.168	1.079	0.993 to 1.173
WC	1.023	0.987 to 1.061	1.035	0.997 to 1.075
Low HDL-C dyslipidaemia‡				
Boys				
Year 2006 vs1996	1.889	1.271 to 2.809	–	–
BMI	1.135	1.087 to 1.184	1.134	1.086 to 1.185
WC	1.054	1.036 to 1.072	1.051	1.032 to 1.070
Girls				
Year 2006 vs1996	1.158	0.612 to 2.191	–	–
BMI	1.201	1.124 to 1.283	1.208	1.130 to 1.292
WC	1.087	1.055 to 1.120	1.094	1.060 to 1.129
Dyslipidaemia§				
Boys				
Year 2006 vs1996	1.985	1.482 to 2.657	–	–
BMI	1.135	1.097 to 1.174	1.135	1.096 to 1.175
WC	1.056	1.041 to 1.070	1.052	1.037 to 1.067
Girls				
Year 2006 vs1996	1.855	1.377 to 2.501	–	–
BMI	1.070	1.030 to 1.113	1.071	1.029 to 1.114
WC	1.043	1.026 to 1.061	1.034	1.016 to 1.053

Model 1: univariate analyses for year 2006 vs 1996, increase of one unit BMI or WC (BMI: 1 kg/m^2; WC: 1 cm).
Model 2: further adjusting for age, cigarette smoking, alcohol drinking, puberty status and year trend.
*Hypercholesterolaemia is taken as cholesterol greater than or equal to the 90th centile of age-specific, gender-specific and height-specific strata.
†Hypertriglyceridaemia is taken as serum triglyceride greater than or equal to the 95th centile of age-specific, gender-specific and height-specific strata.
‡Low HDL dyslipidaemia is taken as serum HDL-C of age-specific, gender-specific and height-specific strata.
§Dyslipidaemia is taken as serum cholesterol, TGs, HDL-C of age-specific, gender-specific and height-specific strata.
BMI, body mass index; HDL, high-density lipoprotein; HDL-C, HDL-cholesterol; TGs, triglycerides; WC, waist circumference.

to 2006. Examination of the anthropometric and lipid statuses over the 10-year period found an increase in hypercholesterolaemia and dyslipidaemia in both sexes and an increase in low HDL dyslipidaemia in boys. Prevalence of hypertriglyceridaemia and low HDL dyslipidaemia increased in boys, but not in girls. BMI was associated with hypertriglyceridaemia, low HDL dyslipidaemia and dyslipidaemia in boys and low HDL dyslipidaemia in girls. WC showed similar associations, however, to a much lower degree.

There are several limitations to be noted in the calculation and interpretation of our anthropometric results. First, the cross-sectional study design may have yielded biased results; however, the large sample size should make up for any students who had any medical history or treatments. Second, the measurement bias of the cut-off points of BMI in the definition of overweight and obese that may have biased this association between adiposity and lipid characteristics. Using a universal BMI cut-off point for overweight and obesity may not be

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appropriate for comparing the prevalence of obesity and its association with abnormal lipid profiles among different ethnic groups. Third, we used GLM and multivariate regression models to examine the prevalence of dyslipidaemia which may be associated with somewhat biased results. Finally, we did not assess the different factors which may have impacted the trend such as diet, puberty, alcohol or smoking habits. Further assessment of environmental factors, such as nutritional condition, dietary and physical activity habits, may have garnered greater insight on the relationship among those factors and dyslipidaemia.

The increase in overweight and obesity mirrors secular trends in adolescent weight status found in the USA during the 1980s and 1990s in the US NHANES (National Health and Nutrition Examination Survey) studies.[23] Similarly, trends in dyslipidaemia found in our study were similar to findings from the Princeton School study, Bogalusa Heart study and Minneapolis Blood Pressure study. The Princeton study also reported a higher prevalence in hypercholesterolaemia (8–14.8%) in the study participants from 1975 to 1990.[24] Likewise, studies carried out in North Indian and Greek populations have shown similar trends in weight status and dyslipidaemia.[25 26] The North Indian study reported a decline in HDL-C levels for boys (−4.6 mg/dL) and a smaller non-significant difference in girls.[26] Greek school-aged boys were found to have higher mean TC (5.8 mg/dL) and TGs (10.8 mg/dL), and lower HDL-C (−16.9 mg/dL).[25] The increase in abnormal lipid statuses in children with rising childhood obesity corresponds with epidemiological evidence of obesity-caused dyslipidaemia and mechanisms of the obesity–dyslipidaemia linkage.[27]

Secular trends in weight status have varied widely among different countries. A study of 18-year-old boys in Austria also reported a decrease in TC level and increase in TGs despite an increased prevalence of overweight (13.3–15.7%) and obesity (2.6–5.4%) between 1986 and 2005.[28] An even larger trend in decreased cholesterol level was also reported in Finland and Swedish adolescents.[29 30] Several studies have cited physical activity as an important factor for determining abnormal lipid status. A Welsh study that compared the cardiovascular risk factors in 12–13-year-olds, between 2002 and 2007, found improvements in mean lipid concentrations in both sexes. No change in dietary habits was reported, but there was a significant increase in physical activity.[31]

Our results showed that overweight children faced a higher risk of dyslipidaemia and low HDL dyslipidaemia than those at normal weight. Overweight boys also faced a higher risk of hypertriglyceridaemia than normal weight boys. Several studies reported similar associations between weight status and lipid levels in adolescents. In a study on Korean male adolescents divided into three groups according to BMI tertiles, Kim *et al* reported that the heaviest group showed the highest levels of abnormal lipid statuses.[32] Christian *et al* also reported an OR of 3.0 for obese men and 2.9 for obese women for low HDL dyslipidaemia from the US NHANES 2005–2008 study.[33] The same study also found elevated risk for hypertriglyceridaemia with an even higher OR of 8.2 and 13.4 for boys and girls, respectively. In a Chinese study, with cut-offs determined by WC, overweight (>75–90th centile) and obese (>90th centile) adolescents had an OR of 1.7 and 3.8, respectively, for dyslipidaemia.[34]

It has also been reported that directly measured body fat percentage was associated with lipid concentrations in adolescents in the USA. The β coefficients of linear regression models for TC, HDL-C and TGs were 0.94, −0.45 and 1.02, respectively, for boys, and 0.55, −0.45 and 1.01, respectively, for girls. However, Lamb *et al* note that body fat percentage accounted for 2–20% of the variation in lipid concentrations, suggesting family history and pubertal status as other factors that might influence lipid concentrations in youths.[35]

BMI and WC are indirect measurements of body fat that are more convenient methods to screen for dyslipidaemia in adolescents. Our results showed BMI and WC statistically elevated the risk of hypertriglyceridaemia, low HDL-C dyslipidaemia and dyslipidaemia. Per unit BMI or WC increase, each abnormal blood lipid status was more strongly associated with increases in BMI. For the unit increment in BMI, the OR for hypertriglyceridaemia was 1.29 and 1.07 for boys and girls, respectively. For low HDL-C dyslipidaemia, the OR was 1.13 and 1.25 for boys and girls, respectively. Boys had a higher association between each unit increase in BMI and dyslipidaemia, with an OR of 1.13, whereas the OR for girls was 1.06. Another study on adolescents in the USA reported an association between BMI-determined obesity and TG/HDL ratio (r=0.18).[36] However, other studies have pointed out that WC within BMI category was better than BMI alone in identifying individuals with higher levels of abdominal fat, and may identify normal or overweight BMI individuals with CVD risk factors.[34 37] This should be taken into consideration as a possible approach to screening dyslipidaemia in adolescents.

In order to prevent or mitigate the increasing trend of dyslipidaemia in the future, we recommend an early screening prevention programme for high risk, overweight and obese individuals, followed by a population-based intervention programme.[38] Identification of children and adolescents at a high risk of CVD includes general assessments provided by paediatric care providers and parents and screening for risk assessments such as lipids and lipoprotein levels, BP, body size and family history. These risk interventions include dietary, behavioural and pharmacological approaches, which are key factors in the prevention of dyslipidaemia among children and adolescents.[39 40]

In summary, our analyses of cross-sectional survey from 1996 to 2006 data from the Taipei Children Heart Studies showed an increase in mean weight and BMI in adolescent boys, and dyslipidaemia prevalence in both sexes. The data also showed an increased risk of

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dyslipidaemia in overweight children compared with normal weight children. A significant association between BMI and dyslipidaemia was noted. However, further studies are warranted to elucidate how dyslipidaemia, obesity and health behaviours have changed over time in Taiwan. We predict that this trend will be seen again if conducted in the future, such as in 2016, due to the current diet and lifestyle habits of children. We recommend that screening for obese adolescents would be an ideal tool to develop an intervention programme for obesity-related comorbidities in the future. We believe that health education, healthy eating behaviours and physical activity programmes will result in successful intervention programmes.

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