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Association between Adiponectin Levels and Abdominal Obesity among a Population of Secondary School Children in Vietnam

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Abstract

Background: The rate of childhood obesity is rising across the world. The relationship between the level of adiponectin, which is a known marker for metabolic syndrome, and Abdominal Obesity (AO) among children are reported in various reports worldwide; however, there has not been such a research in Vietnam. This study aims to investigate adiponectin levels and its association with abdominal obesity among Vietnamese schoolchildren.

Methods: We included 821 grade six students from four randomly selected secondary schools in Hanoi for anthropometric measurements and collecting biochemical samples for blood adiponectin, HbA1C, HDL-C, and LDL-C concentration analysis. AO was identified by waist-to-height ratio (WHtR) of ≥ 0.5. Mann-Whitney's U test was performed to compare abdominal and non-abdominal obesity among boys and girls. Logistic regression analyses were performed to determine the association of AO and body mass index (BMI) with adiponectin levels.

Results: Adiponectin levels were lower in boys (7.65 µg/mL) than in girls (8.79 µg/mL). The percentage of boys with adiponectin levels less than the median was 39.64% in the non-AO group and 66.45% in the AO group, while the percentage for girls were 47.01% in the non-AO group and 74.07% in the AO group. When adiponectin levels were below median, the adjusted odd ratios (aOR) of AO and BMI at 95% confidence intervals were 2.89 (1.74-4.89) in boys and 2.55 (1.27-5.12) in girls and 2.73 (1.66-4.49) in boys and 1.96 (1.16-3.31) in girls, respectively.

Conclusions: Regardless of sex, among schoolchildren, adiponectin levels are significantly different between abdominal and non-abdominal obesity groups. Adiponectin generates a clearer effect on AO in boys, and the aOR of AO is higher than BMI aOR. These results suggest that preventing AO could improve the levels of adiponectin in schoolchildren, which will consequently prevent metabolic syndrome and non-communicable diseases in the future.

Keywords: Adiponectin; Abdominal obesity; Obesity; Children; Metabolic syndrome

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Introduction

The rate of childhood obesity is rising across the world, resulting in heavy burdens related to corresponding non-infectious diseases [1]. In a systematic review by Reilly and Kelly, it was found that children and teenagers with overweight and obesity are at a 1.1 to 5.1 times higher risk of developing coronary heart disease, hypertension, diabetes mellitus, and strokes; childhood obesity also increases the risk of premature mortality by 1.4 to 2.9 times in adolescents [2]. Therefore, the prevention and control of childhood obesity are of vital importance. The

International Diabetes Federation (IDF) diagnostic criteria for pediatric metabolic syndrome include the presence of excessive abdominal fat, besides two or more other factors (elevated triglycerides, low levels of high-density lipoprotein cholesterol (HDL-C), high blood pressure, elevated plasma glucose) [3]. In diagnosing pediatric obesity, the IDF recommends measuring waist circumferences (WC) rather than the body mass index (BMI). In children, the WC correlates more strongly with the amount of visceral adipose tissue compared to in adults and is capable of being used as an independent predictor of insulin resistance, lipid levels, and blood pressure. Abdominal obesity (AO) can thus be used as the core criteria in diagnosing metabolic syndromes. In children, AO is determined by waist circumference measurements of above the 90th percentile (3). Recently, in an increasing number of research studies involving adolescent subjects, WC, WHtR, and BMI have been recognized as factors for predicting chronic diseases, glucose metabolism disorders, abnormal lipid profiles, and hypertension; among these factors, the use of WHtR is assessed as being more effective than that of WC and BMI in predicting hypertension, diabetes mellitus, blood lipid disorders, and other metabolic syndromes [4,5]. A meta-analysis by Savva et al. revealed that calculating the relative risk ratio (rRR) of RRBMI/RRWHtR demonstrated the advantage of WHtR over BMI in screening for diabetes mellitus [6]. Adiponectin, one of the adipocytokines that are excreted by the adipose tissue in body fat and that circulate as multimers in the body, has the function of sensitizing the body to insulin [7]. In adolescent patients with obesity, low levels of serum adiponectin were found to be associated with higher risks of atherosclerosis, hypertension, glucose resistance, and lipid disorders [8]. Adiponectin has a similar structure to that of collagen, and adiponectin receptors (AdipoR1 and AdipoR2) are chiefly found in the liver and muscle tissues [9]. AdipoR1 and AdipoR2 act as adiponectin metabolism mediators in the body, and the multiplication and upregulation of AdipoR1 and AdipoR2 are very important factors in the mediation of insulin resistance. Whitehead et al. and Turer et al. [10] reported that high levels of serum adiponectin are beneficial in preventing arteriosclerosis and myocardial infarction as well as in reversing several kidney disorders and inflammation by reducing the glucose output and lipogenesis levels in the liver [11,12]. Several other studies have revealed the extensive effect of low adiponectin levels in inducing metabolic syndromes in children with obesity. Ogawa et al. [13-15] studied 100 Japanese schoolchildren with obesity who were aged between 8 to 10 years and found that serum adiponectin levels were inversely correlated with the abdominal circumference ($r = -0.243$; $p < 0.05$) [8]. These results are in line with those of the study by Cnop et al. [16] involving 182 healthy adults aged between 32 to 75 years, in which plasma adiponectin levels and WHtR were also found to be inversely correlated ($r = -0.380$; $p < 0.0001$) [16]. In Vietnam, health check-ups for schoolchildren are performed annually with no additional cost to tuition fees. However, there has never been a research study on diagnosing childhood obesity using the two parameters, serum adiponectin level and abdominal circumference. Therefore, this study was carried out for the first time in Vietnam with the aim of evaluating the levels of adiponectin in children and of investigating the relationship between the adiponectin level and AO in a population of Vietnamese secondary schoolchildren aging from 11 to 12 years old.with NAFLD/NASH.

Methods

The study was carried out in 8 days in January 2014, based in Hanoi. It is a cross-sectional study that involved the use of stratified random sampling method and laboratory biochemical analysis for blood adiponectin concentration. Two urban districts were randomly selected from four central districts in urban Hanoi. Subsequently, using random selection, four schools were chosen from 29 public junior high schools in the two selected urban districts. Random selection was used for selecting five grade six classes from each of the four selected schools for collecting data and biochemical samples for blood adiponectin, HbA1C, HDL-C, and LDL-C concentration analysis.

Subjects

There were 1417 students of 11 to 12 years old in grade 6 from four selected secondary schools participated in the study. Five classes from each school are randomly selected, narrowing down total participants to 936 students. 824 students and their parents consented to participate in the study, and 3 students withdrew from the study later on. Overall, there were 821 grade 6 students, aging 11 to 12 years and accepted to participate in the study.

Anthropometric measurements

Anthropometric measurements were collected by two groups, each included two doctors and three nutritionists, measuring the weight of each student using Dretec BS-150WT digital weighing scales (Dretec, Saitama, Japan) that are calibrated to within 100g standard error [17,18]. The students were requested to remove their footwears and all heavy items such as jackets, belts, key chains, and mobile phones. Height measurements were taken using standard meter scales with a precision to 0.1 cm; the meter scales were placed vertically, i.e., perpendicular to the ground. The students removed their footwears and subsequently stood with their back against the meter scale while looking straight ahead and keeping their hands at their sides. A measuring tape was used to measure the circumferences of the waist and hips. The results of the height and circumferential measurements were recorded in centimeters to up to one decimal place [17,18]. Arterial blood pressure was measured using HEM–7051 electronic sphygmomanometers (OMRON, Kyoto, Japan). The BMI values were categorized based on the World Health Organization (WHO) guidelines for BMI in children aged between 5 and 19 years [19].

Biochemical samples collection and analysis

The process of blood sample collection for biochemical analysis was carried out at four selected schools in eight subsequent days in January 2014. Japanese and Vietnamese medical doctors and nurses from NCGM Hospital (Tokyo, Japan) and Bach Mai Hospital (Hanoi, Vietnam) were present at all study sites, for the entire duration of the study, to provide diagnostic screening, decide which student were suitable for blood sampling, supervise all blood collecting procedures carried out by Bach Mai Hospital pediatric nurses, and provide on-site interventions in case of an

emergency. Laboratory tests were conducted in the Biochemistry Department of Bach Mai Hospital, Hanoi, Vietnam, according to the International Organization for Standardization (ISO) 15189 standard. The students were requested to skip breakfast on the day of blood sample collection, for which they had to fast for at least 10 hours. The adequacy of the fasting period was confirmed before blood samples were collected. Between 7:30–10:00 AM, 5 mL of venous blood per student was collected by the nurses of Pediatric Department of Bach Mai Hospital in tubes containing 1g/L of ethylenediaminetetraacetic acid as an anticoagulant. Subsequently, the samples were placed on dry ice at the collection site and were then transported to the Biochemistry Department of Bach Mai Hospital at the end of the morning of the same day. The samples were centrifuged at 5000 rpm for 10 min. The plasma glucose level was determined using the glucose hexokinase method with a Cobas® 8000 (c702) chemistry analyzer (Roche, Basel, Switzerland). The glycated hemoglobin (HbA1C) level was measured using the boronate affinity high-performance liquid chromatography method with an Ultra2 chromatograph (Primus Diagnostics, Kansas City, MO, USA). Triglyceride, cholesterol, HDL-C, and low-density lipoprotein cholesterol (LDL-C) levels were measured using an automated colorimetric enzyme assay kit with a Cobas® 8000 (e702) chemistry analyzer (Roche) [17]. Serum adiponectin values were measured by a latex particle-enhanced turbidimetric assay kit (LSI Medience Corporation, Tokyo, Japan) using Backman Coulter AU 2700 [20].

Definition of Abdominal Obesity (AO)

Childhood AO was defined as a WHtR ≥ 0.5 according to the diagnostic criteria for metabolic syndrome [21, 22].

Ethical considerations

The study protocol was approved by the Ethics Committee of Bach Mai Hospital, Hanoi, Vietnam, with the decision letter number 529 QD-BM on May 10, 2013, and the Ethics Committee of the National Center for Global Health and Medicine, Japan, with the number 1496 on October 1, 2013. Information sheets and consent forms were distributed to parents and students by school educators before health screening and blood samples collection. Consent for research publication were also obtained from all students and parents. Students participated in the study agreed to provide written informed consent forms along with written approval forms from their parent(s). All students could withdraw from the study at any time without any consequences. Students' information were codified and kept anonymous. All on-site blood sampling procedures were supervised and directed by experienced medical professionals from both Japan and Vietnam. Emergency and on-site care for students before and after blood sampling were provided by both educators and all medical staffs. All students were instructed to exit blood sampling site if they felt unwell or uncomfortable, even if medical doctors from health screening teams allowed them to participate in blood samples collecting. Regardless of their participation or withdrawal from blood sampling, each student participated in the study received standard compensation gifts of one Dretec BS-150WT digital weighing scales (Dretec, Saitama, Japan), and one OMRON S.T.E.P.S HJ-107 pedometer (OMRON, Kyoto, Japan). All students participated in blood sampling, besides standard compensation gifts, received comprehensive blood test results performed by Bach Mai Hospital's Biochemistry Department at no additional cost.

Statistical analysis

The Shapiro-Wilk test was used to test for normal distribution. The Mann-Whitney U test was used to compare characteristics between the groups. P values of less than 0.05 were considered statistically significant. Univariate and multivariate logistic regression tests were performed to determine the odds ratio (OR) and adjusted odds ratio (aOR) at the 95% confidence interval (CI) in order to identify the factors associated with AO and non-AO. All the data analyses were performed using the SPSS statistics desktop version 21.0 media pack software (IBM, Armonk, NY, USA).

Results

Between the boys and girls, there were statistically significant differences in BMI (median: 19.58 kg/m2 vs. 18.13 kg/m2; $p < 0.001$), waist circumference (median: 70.25 cm vs. 65.00 cm; $p < 0.001$), and serum adiponectin levels (median: 7.65 µg/mL vs. 8.79 µg/mL; $p < 0.001$), respectively. The adiponectin level was significantly negatively correlated with WHtR (schoolboys: $r = 0.297$, $P < 0.001$ and schoolgirls: $r = 0.243$, $P < 0.001$). **Table 1** presents the characteristics of the schoolboys in the AO and non-AO groups. The differences between the two groups were statistically significant in terms of all the parameters except for height and the T-cholesterol, fasting glucose, and HbA1c levels ($p \leq 0.001$). As for the adiponectin and HDL-C levels, the values were significantly lower in the AO group than in the non-AO group. The other measured values were higher in the AO group than in the non-AO group. Regarding the adiponectin levels, the median value in the non-AO group was 9.07 ± 3.65 µg/mL, while that in the AO group was 7.14 ± 2.8 µg/mL ($p < 0.001$). With respect to waist circumference (WC) as a measurement of AO, the value in the non-AO group was 64.77 ± 6.21 cm, while that in the AO group was 79.94 ± 5.74 cm ($p < 0.001$). **Table 2** presents the characteristics of the schoolgirls in the AO and non-AO groups. Similar trends were observed in the measured parameters, apart from in the lipid profiles, between the girls in the AO and non-AO groups. Further, apart from the differences in height and the T-cholesterol, fasting glucose, HbA1c, HDL-C, and LDL-C levels, those in all the other parameters were statistically significant between the AO and non-AO groups ($p < 0.001$). The median adiponectin level in the non-AO group was 9.96 ± 3.89 µg/mL, while that in the AO group was 7.82 ± 3.15 µg/mL ($p < 0.001$). The waist circumference in the non-AO group was 64.16 ± 5.60 cm and that in the AO group was 79.87 ± 6.26 cm ($p < 0.001$). **Table 3** presents the results of the univariate and multiple logistic regression analyses performed to determine the association between the adiponectin level and obesity in the boys and girls based on the WHtR and BMI calculations.The percentage of boys with adiponectin levels of less than the median was 39.64% in the non-AO group and 66.45% in the AO group, while the percentage of girls was 47.01% in the non-AO group and 74.07% in the AO group.On applying the WHtR calculation in boys, the OR at the

Table 1: Abdominal obesity and abdominal obesity groups.

	Factors	Non-AO group (n = 224)	AO group (n = 156)	P value*
Height (cm)	Median (IQR)	146.20 (141.27 - 152.00)	147.95 (144.00 - 151.50)	0.212
	Mean ± SD (95% CI)	146.86 ± 7.77 (127.50 - 172.20)	147.53 ± 6.31 (131.60 - 164.00)	
Weight (kg)	Median (IQR)	37.85 (33.83 - 42.83)	49.30 (45.00 - 55.65)	< 0.001
	Mean ± SD (95% CI)	38.57 ± 7.84 (22.00 - 76.70)	50.36 ± 8.46 (33.00 - 76.40)	
BMI (kg/m^2)	Median (IQR)	17.76 (16.05 - 19.40)	22.55 (21.27 - 24.44)	< 0.001
	Mean ± SD (95% CI)	17.73 ± 2.23 (12.07 - 26.23)	23.02 ± 2.71 (15.70 - 34.97)	
WC (cm)	Median (IQR)	65.00 (60.00 - 69.00)	80.00 (76.00 - 83.00)	< 0.001
	Mean ± SD (95% CI)	64.77 ± 6.21 (46.00 - 84.00)	79.94 ± 5.74 (66.50 - 99.00)	
WHtR	Median (IQR)	0.44 (0.41 - 0.47)	0.53 (0.52 - 0.56)	< 0.001
	Mean ± SD (95% CI)	0.44 ± 0.04 (0.34 - 0.50)	0.54 ± 0.03 (0.50 - 0.66)	
Adiponectin (µg/mL)	Median (IQR)	8.28 (6.28 - 11.25)	6.63 (5.00 - 8.79)	< 0.001
	Mean ± SD (95% CI)	9.07 ± 3.65 (2.58 - 22.58)	7.14 ± 2.83 (3.06 - 16.97)	
LDL-C (mmol/L)	Median (IQR)	2.21 (1.81 - 2.65)	2.51 (1.93 - 2.90)	0.001
	Mean ± SD (95% CI)	2.28 ± 0.67 (0.57 - 4.64)	2.49 ± 0.74 (0.74 - 4.54)	
T-cholesterol (mmol/L)	Median (IQR)	4.19 (3.76 - 4.63)	4.34 (3.84 - 4.89)	0.062
	Mean ± SD (95% CI)	4.26 ± 0.74 (2.05 - 3.76)	4.42 ± 0.83 (2.81 - 6.98)	
Fasting Glucose (mmol/L)	Median (IQR)	4.90 (4.50 - 5.20)	4.80 (4.50 - 5.10)	0.342
	Mean ± SD (95% CI)	4.87 ± 0.50 (3.70 - 6.90)	4.83 ± 0.53 (3.70 - 7.90)	
HbA1c (%)	Median (IQR)	5.40 (5.30 - 5.60)	5.50 (5.30 - 5.60)	0.524
	Mean ± SD (95% CI)	5.43 ± 0.26 (4.20 - 6.00)	5.45 ± 0.26 (4.50 - 6.10)	
HDL-C (mmol/L)	Median (IQR)	1.51 (1.27 - 1.82)	1.35 (1.13 - 1.57)	< 0.001
	Mean ± SD (95% CI)	1.58 ± 0.42 (0.85 - 2.95)	1.37 ± 0.32 (0.72 - 2.60)	
Triglycerides (mmol/L)	Median (IQR)	0.80 (0.59 - 1.06)	1.07 (0.82 - 1.50)	< 0.001
	Mean ± SD (95% CI)	0.90 ± 0.45 (0.33 - 3.03)	1.25 ± 0.73 (0.43 - 5.73)	

IQR, interquartile range (25th percentile-75th percentile); SD, standard deviation; CI, confidence interval; BMI, body mass index; AO, abdominal obesity; WC, waist circumference; WHtR, waist-to-height ratio; LDL-C, low density lipoprotein cholesterol; HbA1c, glycated hemaglobin; HDL-C, high density lipoprotein cholesterol.

Table 2: Comparison between the characteristics of the girls in the non-abdominal obesity and abdominal obesity groups.

Factors		Non-AO group (n = 387)	AO group (n = 54)	P value*
Height (cm)	Median (IQR)	148.30 (143.50 - 153.00)	149.15 (144.38 - 154.00)	0.441
	Mean ± SD (95% CI)	148.23 ± 6.71 (126.00 - 169.00)	149.14 ± 6.23 (136.00 - 164.00)	
Weight (kg)	Median (IQR)	39.60 (34.40 - 44.00)	48.25 (43.98 - 54.93)	< 0.001
	Mean ± SD (95% CI)	39.63 ± 7.06 (22.00 - 58.90)	49.37 ± 7.74 (33.50 - 69.80)	
BMI (kg/m2)	Median (IQR)	17.73 (16.27 - 19.44)	21.88 (20.43 - 23.90)	< 0.001
	Mean ± SD (95% CI)	17.93 ± 2.25 (12.50 - 25.10)	22.12 ± 2.67 (17.05 - 31.31)	
WC (cm)	Median (IQR)	64.00 (60.00 - 68.00)	79.00 (76.00 - 82.50)	< 0.001
	Mean ± SD (95% CI)	64.16 ± 5.60 (46.00 - 78.00)	79.87 ± 6.26 (70.00 - 99.90)	
WHtR	Median (IQR)	0.43 (0.41 - 0.46)	0.52 (0.51 - 0.55)	< 0.001
	Mean ± SD (95% CI)	0.43 ± 0.03 (0.34 - 0.50)	0.54 ± 0.04 (0.50 - 0.67)	
Adiponectin (µg/mL)	Median (IQR)	9.20 (7.29 - 11.92)	7.25 (5.51 - 9.34)	< 0.001
	Mean ± SD (95% CI)	9.96 ± 3.89 (2.88 - 30.69)	7.82 ± 3.15 (3.36 - 19.63)	
LDL-C (mmol/L)	Median (IQR)	2.20 (1.79 - 2.59)	2.47 (1.89 - 2.71)	0.063
	Mean ± SD (95% CI)	2.18 ± 0.64 (0.64 - 6.10)	2.37 ± 0.72 (1.08 - 5.50)	
T-cholesterol (mmol/L)	Median (IQR)	4.12 (3.68 - 4.61)	4.46 (3.74 - 4.97)	0.051
	Mean ± SD (95% CI)	4.17 ± 0.70 (2.24 - 7.27)	4.42 ± 0.86 (2.59 - 7.68)	
Fasting Glucose (mmol/L)	Median (IQR)	4.80 (4.40 - 5.10)	4.80 (4.50 - 5.22)	0.339
	Mean ± SD (95% CI)	4.77 ± 0.54 (3.40 - 6.50)	4.84 ± 0.52 (3.20 - 5.70)	
HbA1c (%)	Median (IQR)	5.40 (5.30 - 5.60)	5.45 (5.30 - 5.70)	0.122
	Mean ± SD (95% CI)	5.41 ± 0.24 (4.60 - 6.20)	5.48 ± 0.26 (4.90 - 6.00)	
HDL-C (mmol/L)	Median (IQR)	1.46 (1.20 - 1.74)	1.40 (1.07 - 1.62)	.056
	Mean ± SD (95% CI)	1.51 ± 0.41 (0.74 - 2.95)	1.38 ± 0.34 (0.78 - 2.07)	
Triglycerides (mmol/L)	Median (IQR)	0.96 (0.74 - 1.25)	1.22 (0.95 - 1.90)	< 0.001
	Mean ± SD (95% CI)	1.06 ± 0.48 (0.37 - 5.59)	1.47 ± 0.79 (0.55 - 4.32)	

IQR, interquartile range (25th percentile-75th percentile); SD, standard deviation; CI, confidence interval; BMI, body mass index; AO, abdominal obesity; WC, waist circumference; WHtR, waist-to-height ratio; LDL-C, low density lipoprotein cholesterol; HbA1c, glycated hemaglobin; HDL-C, high density lipoprotein cholesterol.

* Mann-Whitney U Test

Table 3: The results of the logistic regression analysis for determining the association between adiponectin levels and obesity in boys and girls.

Association of adiponectin level with abdominal obesity and non-abdominal obesity caculated based on WHtR in boys and girls											
	Adiponectin Median (µg/mL)	Non-AO n (%)	AO n (%)	OR	95% CI		P value	aOR	95% CI		P value
					Lower	Upper			Lower	Upper	
Boys	≤ 7.65	88 (39.64)	103 (66.45)	3.02	1.97	4.63	< 0.001	2.89	1.74	4.89	< 0.001
	> 7.65	134 (60.36)	52 (33.55)	1.00				1.00			
Girls	≤ 8.79	181 (47.01)	40 (74.07)	3.22	1.70	6.11	< 0.001	2.55	1.27	5.12	< 0.009
	> 8.79	204 (52.99)	14 (25.93)	1.00				1.00			
Association of adiponectin level with overweight/obesity and non-overweight/non-obesity caculated based on BMI category in boys and girls											
	Adiponectin Median (µg/mL)	Non-OW/OB n (%)	OW/OB n (%)	OR	95% CI		P value	aOR	95% CI		P value
					Lower	Upper			Lower	Upper	
Boys	≤ 7.65	71 (38.80)	120 (61.86)	2.56	1.69	3.87	< 0.001	2.73	1.66	4.49	< 0.001
	> 7.65	112 (61.20)	74 (38.14)	1.00				1.00			
Girls	≤ 8.79	152 (45.10)	69 (67.65)	2.55	1.60	4.06	< 0.001	1.96	1.16	3.31	< 0.012
	> 8.79	185 (54.90)	33 (32.35)	1.00				1.00			
OR calculated by a logistic regression univariate analysis.											
aOR calculated with a multivariate logistic regression analysis by adjusting for birth weight, sleep duration, father's BMI, and mother's BMI.											
AO defined according to WHtR > 0.5 (20, 21).											
AO, abdominal obesity; WHtr, waist-to-height ratio; CI, confidence interval; OR, odds ratio; aOR; adjusted odds ratio; BMI, body mass index.											

95% CI of adiponectin levels that were less than or equal to the median value in the AO group was 3.02 (OR: 3.02, CI: 1.97 – 4.63). The aOR at the 95% CI of the adiponectin levels that were less than or equal to the median value in the boys in the AO group was 2.89 (aOR: 2.89, CI: 1.66 – 4.49). When the BMI calculations were applied, the OR and aOR at the 95% CI of the adiponectin levels of less than or equal to the median value in the boys in the AO group were lower than those associated with the WHtR calculations (OR: 2.56, CI: 1.69 - 3.87 | aOR: 2.73, CI: 1.66 – 4.49), indicating a less significant association between the adiponectin level and BMI-based obesity compared with that between the adiponectin level and WHtR-based obesity. Regarding obesity in girls, the OR and aOR at the 95% CI of the adiponectin levels that were less than or equal to the median value in the AO group based on the WHtR calculations (OR: 3.22, CI: 1.70 – 6.11 | aOR: 2.55, CI: 1.27 – 5.12) were higher than the respective OR and aOR based on the BMI calculations (OR: 2.55, CI: 1.60 – 4.06 | aOR: 1.96, CI: 1.16 – 3.31). This trend was similar to the one observed in the boys, suggesting that WHtR is a more significant metric than BMI in assessing the association between the adiponectin level and obesity.

Discussion

This is the first research study conducted in Vietnam with the aim of investigating the adiponectin levels as well as the relation between the adiponectin level and AO in secondary school students. The average adiponectin level was 7.65 µg/mL in the boys in the AO group, 8.79 µg/mL in girls in the AO group, 9.07 µg/mL in the boys in the non-AO group, and 9.96 µg/mL in the girls in the non-AO group. On comparing these findings with those of other research studies worldwide, we found that the study by Yoo et al. [23] generated relatively similar results to ours in the non-AO groups (Adiponectin levels: 8.09 ± 3.50 µg/mL in non-AO boys and 9.10 ± 3.44 µg/mL in non-AO girls). There were, however, several other studies in which higher average adiponectin levels than those from studies in Vietnam were reported (Normal: 14.6 – 18.7 µg/mL; overweight/obesity: 13.2 – 15 µg/mL) [24,25]. Most of the anthropometric parameters in the AO groups were higher than those in the non-AO groups, regardless of sex. The adiponectin level was lower in the AO group than in the non-AO group in both the sexes. These results were similar to those of several previous studies. One study in Japan showed the connection between AO and adiponectin levels among population-based schoolchildren [26]. Adiponectin is one of the best predictive metrics for metabolic disorders. Gilardini et al. [27] pointed out that obesity in children and teenagers was linked with higher risks of cardiovascular diseases [27]. A large body of evidence supports the observation that a low adiponectin level is linked to findings related to abnormal metabolism, such as insulin resistance and the risk of type 2 diabetes and cardiovascular diseases, in children and adolescents [25-29] Several studies have reported that boys with obesity have a lower average adiponectin level than other similarly aged children [7-14]. Our data revealed that when the individual adiponectin level is lower than or equal to the median value, schoolboys might be at a higher risk (aOR) of AO than schoolgirls. Therefore, our study results suggest that schoolboys could have a higher risk of cardiovascular diseases and type 2 diabetes. Woo et al. demonstrated that the sex-based differences in adiponectin levels are dependent on both the puberty stage and adiposity in adolescents; specifically, by post-puberty, boys with overweight/obesity exhibit the lowest levels of adiponectin [30]. Recently, there were several studies that demonstrated ethnic-, sex-, and age-related differences in adiponectin levels [31-33]. During pubescence, the adiponectin level may be related to hormonal changes and other biochemical elements that are essential to the body's growth [34]. Therefore, sex hormones may be one of the causes behind the sex-related differences in the body's biochemical composition, especially during pubescence [35]. It was suggested that adiponectin is related to the free androgen index and sex hormone-binding globulin levels in adolescents [36].

Children entering this age change both physically and mentally [37)]. This age is also the period during which children are highly susceptible to being overweight and developing diabetes as a result of biochemical composition changes in the body. Excessive weight gain, especially during pubescence, could be maintained during later ages. There were several studies that were focused on evaluating whether lifestyle-related interventions, such as physical activity, contributed to the improvement of adiponectin levels in children with obesity [38, 39]. From the onset of pubescence, diet and exercise programs should be individually modified based on each student's sex and physiological background in order to improve adiponectin levels. Further research studies on adiponectin levels and pubertal hormones are recommended. On calculating the aOR value, it was found that using the relationship between the adiponectin level (lower or equal to the median value) and WHtR is more accurate than using that between the adiponectin level and BMI in assessing the association between AO and the adiponectin level in children of both sexes. In our study, a WHtR of ≥ 0.5 was used as the standard point for assessing the risks of metabolic disorders in pubescent children [40,41]. This standard point was proven to be suitable in individuals of all ages, sexes, and nationalities in prior studies [22-40]. Similar to our results, those of other studies also indicate that the use of WHtR is more sensitive than that of BMI in indicating the risks of AO and obesity-related cardiovascular diseases in the community, especially in children. Meanwhile, using BMI may result in an incorrect assessment of the risk levels of metabolic disorders and cardiovascular diseases in healthy children and in false positives in children with overweight or obesity [22-42]. Another remarkable difference in the results of this study is that the use of aOR values revealed that the effects of adiponectin-induced AO are stronger in boys than in girls. The aOR was calculated via a multivariate logistic regression analysis by adjusting for weight at birth, sleep duration, father's BMI, and mother's BMI. A low-birth-weight in children with obesity was reported to be associated with a lower high molecular weight adiponectin level [43]. Regarding sleep duration, children who slept for 8 hours per day or more exhibited lower overweight/obesity odds than those who slept for less than 8 hours per day [17]. Moreover, the adiponectin level has been proven to be inversely proportional to BMI [44]. Indicated that the serum adiponectin level is inversely proportional to the BMI, WHtR, serum glucose level during hunger, insulin level, triglyceride level, and uric acid concentration while being directly proportional to the HDL-C concentration. Zhang et al. [45] reported that the adiponectin levels are directly proportional to the WHtR in pubescent boys without obesity and that the use of WHtR compared to that of BMI can result in more accurate estimations of adiposity changes in boys [46]. This study showed that WHtR could be used as an important metric in diagnosing metabolic disorders and in predicting the risks of cardiovascular diseases and diabetes mellitus. In children, lifestyle improvement has been reported to be effective in increasing adiponectin values [29]. In situations in which the mass measurement of adiponectin values cannot be used, this measurement could be replaced by WHtR as a predictive indicator of the risks of cardiovascular diseases and diabetes mellitus. Adiponectin levels as well as WHtR could be adopted as indicators in prospective studies on lifestyle-based interventions for the prevention of lifestyle-related diseases in schoolchildren.

Limitations

The study population was limited in terms of the age group included. This research study only focused on secondary school students aged around 11 to 12 years old; therefore, the adiponectin levels in the sample are not representative of the average adiponectin level of Vietnamese children of all ages. Moreover, in this research, AO was calculated by simple waist circumference and height measurements and not by accurate visceral fat measurements.

Conclusions

Our research has illustrated the importance of measuring adiponectin levels in diagnosing metabolic disorders in students aged around 11-12 years old in Hanoi, Vietnam. A significant difference in adiponectin levels was found between the AO and non-AO groups regardless of sex. Therefore, we suggest measuring the adiponectin levels in children from the onset of puberty in order to recommend interventions for the prevention and management of the risk of type 2 diabetes and cardiovascular diseases. We also suggest interventions for the prevention of childhood obesity based on the results of monitoring the adiponectin levels with the cooperation of authorities, policy makers, schools, and families, thereby reducing the societal burden associated with non-infectious diseases in Vietnam, as well as worldwide. Future research studies should be performed with an increased focus on the sex hormone factor in order to clearly elucidate the sex-based differences in the relationship between AO and adiponectin levels.

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Conflict of Interest

The authors declared no conflict of interest

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