RESEARCH

Waist-to-height ratio as a clinical predictor for cardiovascular risks and insulin resistance in children and adolescents with exogenous obesity

Hend Soliman, Samah Ahmed and Amany Ibrahim[*] (ID)

Abstract

Background: Obesity is one of the most challenging clinical syndromes associated with deleterious health problems. Waist-to-height ratio (WHtR), a newer index for abdominal fat assessment, can be a superior tool in the evaluation of cardiometabolic risk. This study aimed to determine the relation between WHtR and lipid cardiovascular risk ratios and insulin resistance (IR) in children and adolescents with exogenous obesity.

Results: This analytical cross-sectional study included 80 children and adolescents with exogenous obesity, compared to 80 age- and sex-matched healthy non-overweight non-obese controls. Fasting lipid profile (total cholesterol (TC), triglyceride (TG), high-density lipoprotein (HDL) and low-density lipoprotein (LDL)), fasting insulin, and fasting blood glucose were done and lipoprotein risk ratios were calculated; TC/HDL, LDL/HDL, non-HDL/HDL, and TG/HDL). In addition, homeostatic model assessment for IR (HOMA IR), triglyceride glucose index (TyG), TyG-BMI, and TyG-WC were calculated. The study group included 55 (34.4%) males and 105 (65.6%) females with a mean age of 13.6 ± 2.22 years. Obese group had significantly higher TC, TG, LDL, non-HDL, LDL/HDL, TC/HDL, non-HDL/HDL, and TG/HDL, with significantly lower HDL. In addition, they had significantly higher FBG, HOMA IR, TyG, TyG-BMI, and TyG-WC indices compared to the control group. There were statistically significant correlations between WHtR and lipid profile, lipid risk ratios and indices of IR. WHtR was found to be an independent predictor of IR by linear regression analysis.

Conclusion: WHtR can be an excellent, easy, and reliable clinical predictor for cardiovascular risk and IR in children and adolescents with exogenous obesity.

Keywords: Exogenous obesity, Insulin resistance, Cardiovascular risks, Waist-to-height ratio, Lipoprotein risk ratios

Background

Obesity represents one of the most serious public health problems of the twenty-first century and can be defined as a state of excessive body adiposity occurring when energy intake chronically exceeds energy expenditure [1]. Moreover, obesity is one of the most complex and challenging clinical syndromes worldwide that can affect children and adults and has an association with numerous deleterious health outcomes as type 2 diabetes mellitus (T2DM), dyslipidemia, hyperinsulinemia, polycystic ovary syndrome, hypertension, coronary heart diseases, as well as many psychosocial and social problems [2–5].

Anthropometric measures such as weight, height, and circumferences are often used in clinical practice due to their low cost and high convenience. Anthropometric measures of abdominal obesity (as waist circumference (WC), Waist-to-hip ratio (WHR)) appear to be strongly associated with metabolic and cardiovascular risk

*Correspondence: amanyatt@yahoo.com
The Diabetes Endocrine and Metabolism, Pediatric Unit (DEMPU), Pediatric Department, Faculty of Medicine, Cairo University, Cairo, Egypt
The work was a retrospective study performed at the outpatient clinic of The Diabetes Endocrine and Metabolism Pediatric Unit.

Soliman *et al. Egyptian Pediatric Association Gazette*   (2021) 69:38

Page 2 of 6

factors [6, 7]. However, waist-to-height ratio (WHtR), a newer index for abdominal fat assessment, has emerged to be a superior tool in the evaluation of cardiometabolic risks [8].

Coronary risk assessment based exclusively on low-density lipoprotein (LDL) cholesterol is not optimal. Several lipoprotein ratios or "atherogenic indices" were identified and proved to be better predictors for cardiovascular disease (CVD) than conventional lipid parameters [9, 10]. Total cholesterol/high-density lipoprotein cholesterol ratio (TC/HDL); known as the atherogenic or Castelli index and LDL/HDL ratio can be also used [9, 11]. In addition, the use of a simple non-HDL calculation in a lipid profile testing, with determination of the new risk factors, can provide a better assessment of the CVD risk [12–14].

Insulin resistance (IR) or impaired insulin sensitivity is considered an important risk factor for metabolic syndrome, T2DM, and CVD. Thus, early detection of IR can help to prevent the manifestation of clinical diseases. Currently, there are various indirect and direct methods to assess IR; the standard method was the euglycemic-hyperinsulinemic clamp technique, originally developed by Defronzo. However, it is a complex, costly, and time-consuming method, making it difficult to be used for routine clinical practice. Therefore, a number of indices for the measurement of IR have been suggested. Triglyceride glucose index (TyG) and TyG-related indices (TyG-BMI and TyG-WC) were found to be excellent surrogate markers of IR [15–17].

The aim of this study is to determine the relation between WHtR and lipid cardiovascular risk ratios (LDL/HDL, TC/HDL, non-HDL/HDL, and TG/HDL ratios) and IR (measured by homeostatic model assessment for IR (HOMA-IR), TyG index, TyG-BMI, and TyG-WC) in children and adolescents with exogenous obesity.

Methods

Study population

This cross-sectional study included 80 children and adolescents with exogenous obesity. Patients were recruited from the Pediatric Endocrine Unit, in the period from May 2018 to May 2019. Subjects were eligible if they had exogenous obesity, were between 10 and 19 years, had a body mass index more than or equal to 95% for age and sex plotted on Egyption growth charts [18] and showing pubertal signs; Tanner stage 2 or more. Subjects with a history of diabetes mellitus, hypothyroidism or other endocrinal disorders, or prepubertal, or those taking any lipid altering drugs or corticosteroids or having obesity due to any endocrinal or syndromic etiology were excluded from the study. Eighty healthy non-overweight

non-obese age- and sex-matched controls were recruited from the general outpatient clinics.

All procedures performed in this study, involving human participants were in accordance with the ethical standards of Cairo University and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Informed consent was obtained from every individual participant or their legal guardians included.

Data collection

All patients and controls were subjected to full history taking laying stress on age, gender, the presence of any associated conditions or complications.

Thorough clinical examination and the following measurements were carried out: height, weight, BMI, waist circumference (WC-measured in centimeters to the nearest 0.1 cm, with a flexible tape, at the level of umbilicus, at the end of expiration with person breathing silently. Hip circumference (HC-measured in centimeters to the nearest 0.1 cm at the level of the greater trochanters, using a flexible tape), waist-hip ratio (WC/HC-calculated as WC divided by HC), and waist-to-height ratio (WHtR-calculated by dividing WC/height).

- Laboratory investigations including fasting lipid profile including: serum cholesterol (TC), triglycerides (TG), high-density lipoproteins (HDL) and low-density lipoproteins (LDL), and fasting blood glucose (FBG).
- Fasting blood glucose was assessed using GOD-PAP enzymatic colorimetric method. Test Kit Catalog No. 250001/250002 (Salucea Inc.). Total cholesterol was assessed using CHOD-PAP Enzymatic-Colorimetric method in Serum Test Kit Catalog No.230001/230002 (Salucea Inc.). Serum triglycerides was assessed using Quantitative Enzymatic-Colorimetric Determination of Triglycerides in Serum Test Kit Catalog No. 2100 (STANBIO LABORATORY- An EKF Diagnostics Company). LDL Cholesterol was assessed using Direct Enzymatic colorimetric Test Kit REF: NS280001 R1 30 ml/R2 10 ml (Salucea Inc.). HDL Cholesterol was assessed using Test Kit Ref: No. 0599 (Stanbio Laboratory (an EKF Diagnostics Company). Serum insulin was assessed using Enzyme Immuno-assay Test Kit Catalog No. E29-072 (Immunospec Corporation).
- Lipoprotein risk ratios were calculated as follows: LDL/HDL was calculated by dividing LDL (mg/dl) by HDL (mg/dl); it should be < 3 in males, < 2.5 in females, TC/HDL by dividing TC (mg/dl) by HDL (mg/dl); it should be below < 4.5 in males, < 4 in females [9], and non-HDL/HDL by dividing non-

Soliman *et al. Egyptian Pediatric Association Gazette* (2021) 69:38

Page 3 of 6

HDL (mg/dl) by HDL (mg/dl); it should be less than 2.845. TG/HDL was calculated by dividing TG (mg/dl) by HDL (mg/dl) [19].

- Insulin resistance (IR) was calculated according to Matthews et al. (1985) using the following equation: HOMA-IR = fasting blood glucose (mg/dl) X fasting insulin (μIU/ml)/405. Cut-off point ≥ 3.16 for HOMA-IR was considered to be risky for insulin resistance [20, 21].
- The TyG index was calculated using the formula: ln [TG (mg/dL) × fasting glucose (mg/dL)/2] [22].
- TyG-BMI: TyG index × BMI and TyG-WC: TyG index × WC [16].

Statistical analysis

Data were analyzed using the statistical package SPSS version 22. Data was summarized as mean and standard deviation for quantitative variables and as frequencies (number of cases) and relative frequencies (percentages) for categorical variables. Unpaired *t* test was used for comparisons between groups. Chi square (C2) test was performed to compare categorical data. Exact test was used instead when the expected frequency is less than 5. *P* values less than 0.05 were considered as statistically significant. Spearman's correlation coefficient was used to test non-parametric variables and Pearson's correlation coefficient to test parametric variables. linear regression analysis was performed between WHtR and HOMA-IR.

Results

The study group included 160 pubertal children and adolescents; 55 (34.4%) males and 105 (65.6%) females with a mean age of 13.6 ± 2.22 years (ranged from 10.2–18.52 years). They were divided into two groups; group (1) included 80 obese children and adolescents, group (2) included 80 healthy non-obese non-overweight children and adolescents as control.

Group 1 (obese group) included 80 obese patients; 30 (37.5 %) males and 50 (62.5 %) females with a mean age of 13.39 ± 2.06 years, while group 2 (control group) included 80 healthy children and adolescents; 25 (31.25 %) males and 55 (68.75%) females with a mean age of 13.83 ± 2.36 years. The two groups were age- and sex-matched (*P* values 0.104, 0.496 respectively). The obese group has significantly higher body mass index (BMI), waist circumference (WC), hip circumference (HC), waist-hip ratio (WHR), and waist-to-height ratio (WHtR) (Table 1).

Regarding the laboratory findings; the obese group has significantly higher TC, TG, LDL, non-HDL, LDL/HDL, TC/HDL, non-HDL/HDL, and TG/HDL, with significantly lower HDL. In addition, they had significantly

higher FBG, HOMA-IR, TyG, TyG-BMI, and TyG-WC indices compared to the control group (Table 2). Moreover, all obese subjects had high HOMA-IR values, however, only 22.5% (18 out of 80) of the control group had their HOMA-IR values above the cut-off point (≥ 3.12).

There was significantly positive correlation between waist-height ratio and BMI, WC, WHR, TC, TG, LDL, non-HDL, LDL/HDL ratio, TC/HDL ratio, non-HDL/HDL ratio, and TG/HDL ratio in addition to, FBG, and HOMA-IR, TyG index, TyG-BMI, and TyG-WC.

Table 1 Demographic and clinical data of the study groups

Variables	Obese (n = 80) Mean $\pm$ SD	Control (n = 80)	*P* value
Age (years)	13.39 ± 2.06	13.83 ± 2.36	0.21
BMI	37.96 ± 6.3	21.19 ± 2.66	< 0.001*
WC (cm)	96 ± 10.35	54.14 ± 3.15	< 0.001*
HC (cm)	100.64 ± 9.12	67.39 ± 3.39	< 0.001*
WHR	0.94 ± 0.08	0.8 ± 0.05	< 0.001*
WHtR	0.64 ± 0.07	0.37 ± 0.04	< 0.001*
	Frequency (%)		
Sex:			0.41
Male	30 (37.5%)	25 (31.25 %)	
Female	50 (62.5%)	55 (68.75%)	

BMI body mass index, *WC* waist circumference, *HC* hip circumference, *WHR* waist-hip ratio, *WHtR* waist-to-height ratio

*P value < 0.05 is considered significant

Table 2 Laboratory data of the study groups

Variables	Obese (n = 80) Mean $\pm$ SD	Control (n = 80)	*P* value
TC (mg/dl)	189.94 ± 37.62	138.6 ± 19.8	< 0.001*
TG (mg/dl)	117.95 ± 35.82	79.83 ± 14.86	< 0.001*
LDL (mg/dl)	121.1 ± 27.7	79.5 ± 11.15	< 0.001*
HDL (mg/dl)	46.54 ± 13.97	54.41 ± 7.43	< 0.001*
Non-HDL (mg/dl)	143.4 ± 36.7	84.18 ± 25.22	< 0.001*
FBG (mg/dl)	104.89 ± 14.05	86.45 ± 9.82	< 0.001*
HOMA-IR	6.8 ± 1.16	3.31 ± 0.9	< 0.001*
TyG index	8.56 ± 0.28	8.06 ± 0.31	< 0.001*
TyG-BMI index	289 ± 20.68	192.64 ± 12.04	< 0.001*
TyG-WC index	898.8 ± 105.74	454.96 ± 26.08	< 0.001*
	Median (range)		
LDL/HDL ratio	2.6 (0.54–6.68)	1.51 (0.77–3.7)	< 0.001*
TC/HDL ratio	3.99 (1.58–11.14)	2.67 (1.38–5.68)	< 0.001*
Non-HDL/HDL ratio	2.99 (0.79–10.14)	1.67 (0.38–4.68)	< 0.001*
TG/HDL ratio	2.58 (1.08–6.95)	1.5 (0.64–3.41)	< 0.001*

TC Total cholesterol, *TG* triglycerides, *HDL* high-density lipoprotein-cholesterol, *LDL* low-density lipoprotein-cholesterol, *FBG* fasting blood glucose, *HOMA-IR* homeostasis model assessment for insulin resistance, *TyG index* triglycerides/glucose index

*P value < 0.05 is considered significant

Table 3 Correlation between waist-height ratio (WHtR) and the clinical and laboratory parameters in the study

Variables	WHtR	
	r value	*P* value
BMI	0.79	< 0.001*
WC	0.97	< 0.001*
WHR	0.79	< 0.001*
TC	0.68	< 0.001*
TG	0.57	< 0.001*
LDL	0.7	< 0.001*
HDL	− 0.4	< 0.001*
Non-HDL	0.74	< 0.001*
HOMA IR	0.81	< 0.001*
LDL/HDL ratio	0.77	< 0.001*
TC/HDL ratio	0.72	< 0.001*
Non-HDL/HDL ratio	0.74	< 0.001*
TG/HDL ratio	0.68	< 0.001*
FBG	0.55	< 0.001*
TyG index	0.8	< 0.001*
TyG-BMI index	0.92	< 0.001*
TyG-WC index	0.99	< 0.001*

BMI body mass index, *WC* waist circumference, *WHR* waist-hip ratio, *WHtR* waist-to-height ratio, *TC* total cholesterol, *TG* triglycerides, *HDL* high-density lipoprotein-cholesterol, *LDL* low-density lipoprotein-cholesterol, *FBG* fasting blood glucose, *HOMA IR* homeostasis model assessment for insulin resistance, *TyG index* triglycerides/glucose index. Pearson's correlation test (parametric variables) or Spearman's correlation (non-parametric variables) for the correlation between variables, considering significance when *p* < 0.05 (5%)

**P* value < 0.05 is considered significant

However, there was a significant negative correlation with HDL (Table 3).

Linear regression analysis was done and proved that WHtR is an independent predictor of IR assessed by HOMA-IR in this study (adjusted $R^2 = 0.65$, $p < 0.001$) (Fig. 1)

Discussion

Obesity in childhood and adolescence is associated with well-known comorbidities. Moreover, regional body fat distribution has an important influence on metabolic and cardiovascular risk factors. Increased visceral fat accumulation is considered a risk factor for CVD, dyslipidemia, hypertension, stroke, and T2DM [23, 24].

In the current study, the measures of visceral obesity (WC, WHR, and WHtR) were significantly higher in obese patients compared to the control group. Moreover, obese children had significantly higher TC, TG, LDL, and non-HDL compared to the control group. This is in line with other studies that found that obesity especially the central obesity was associated with unfavorable lipid profile [25–28].

Estimation of cardiovascular risk is the cornerstone of cardiovascular prevention. Many lipoprotein ratios were defined in an attempt to optimize the predictive capacity of the lipid profile [9]. In our study, lipoprotein risk ratios (LDL/HDL, TC/HDL, non-HDL/HDL, and TG/HDL ratio) were significantly higher in obese children and adolescents compared to the control group. This in agreement with other authors who found that obesity is associated with increased risk for CVD and these ratios had greater predictive value for CVD than conventional lipid parameters used independently [9, 10, 28].

There is a well-known association between obesity and T2DM especially the visceral obesity [29–31]. Visceral obesity plays an important role in the development of T2DM by mobilizing free fatty acids and certain inflammatory cytokines causing IR [30]. Studies have shown that IR is a risk factor for the development of T2DM and CVD in children and adolescents [32, 33].

In this work, fasting blood glucose (FBG), IR assessed by HOMA-IR, TyG index, TyG-BMI, and TyG-WC were significantly higher in the obese group compared to the control group. This is in line with Hussain et al. [30] who found increased incidence of T2DM in obese patients. Also, Hajian-Tilaki and Heidari [34] found a significant correlation between FBG and WHR and explained this by central obesity which correlates with the development of subsequent metabolic abnormalities and cardiovascular morbidity.

In the current study, there were significantly positive correlations between WHtR and BMI, WC, WHR, TC, TG, LDL, non-HDL, LDL/HDL ratio, TC/HDL ratio, non-HDL/HDL ratio, and TG/HDL ratio in addition to, FBG, HOMA-IR, TyG index, TyG-BMI, and TyG-WC. However, there was significant negative correlation with HDL. This agrees with Miralles et al. [8] who analyzed the correlation of WHtR with the other anthropometric variables, and observed a positive significant correlation with BMI, WC, BF%, lipid profile and TG/HDL and significant negative correlation with HDL. Moreover, Jamar et al. [35] found that among anthropometric obesity indicators, WHtR was most closely associated with occurrences of IR and predicted the onset of diabetes in obese individuals as compared with other parameters (BMI, WC, WHR, neck circumference, and body shape index).

Several studies have been recently conducted to demonstrate the accuracy of WHtR in identifying the risks for CVD in obese children and adolescents from healthy youth population; defining cut-offs and centiles for this easily calculated parameter [36–38]. It is also ideal and non-invasive tool in terms of interpretation and measurement to be used in clinical practice.

Potential limitations of our study must be considered. First, this is a cross-sectional rather than a population-based study, which may lead to over-estimation of the prevalence of insulin resistance in obese children Moreover, this
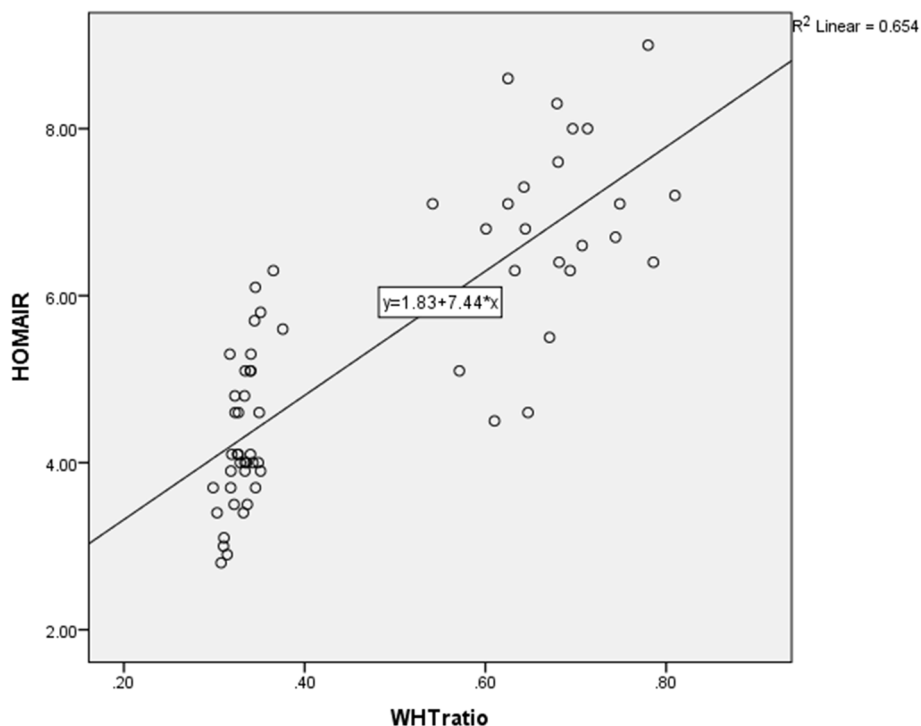
Fig. 1 Linear regression analysis between WHtR and HOMA-IR. R^2 = regression determinant coefficient ($R^2 = 0.65$, $p < 0.001$)

work was a cross-sectional study and might lack adequate evidence of the predictive values of WHtR. Although, this value is not diagnostic; it can be predictor for the screening for IR among obese children and adolescents. Additionally, being based on convenient consecutive sampling this study may lack clear generalizability, however, while applying consecutive sampling, each consecutive eligible patient who presents for care within the defined study time period is approached for enrollment, thus, consecutive sampling provides some structure and additional rigor that reduces the bias in sampling. Finally, blood pressure measurements for the studied subjects were not included in the study.

Conclusion

Waist-to-height ratio (WHtR) can be an excellent, easy and reliable clinical predictor for cardiovascular risk and insulin resistance in children and adolescents with exogenous obesity.

Abbreviations

BMI: Body mass index; CVD: Cardiovascular disease; FBG: Fasting blood glucose; HDL: High-density lipoproteins; HC: Hip circumference; IR: Insulin resistance; LDL: Low-density lipoproteins; T2DM: Type 2 diabetes; TC: Total cholesterol; TG: Triglycerides; TyG index: Triglycerides glucose index; TyG-BMI index: Triglycerides glucose body mass index; TyG-WC index: Triglycerides glucose waist circumference index; WC: Waist circumference; WHtR: Waist-to-height ratio; WHR: Waist-hip ratio.

Availability of data and materials

The datasets used and/or analyzed during this study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The study protocol was approved by the ethical committee of Cairo University Hospital Research Committee. Ethics committee reference number was not available at the time this work was done. A written informed consent was taken from the parents of the study participants. The study and data collection were conformed to all local laws and were compliant with the principles of the Declaration of Helsinki.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Soliman *et al. Egyptian Pediatric Association Gazette*   (2021) 69:38

Page 6 of 6

References

1. Kang MJ, Yang S, Hwang IT (2016) The impact of obesity on hyperandrogenemia in Korean girls. Ann Pediatr Endocrinol Metab 21(4):219–225
2. Aycan Z (2009) Obesity in Childhood: definition and epidemiology. J Clin Res Pediatr Endocrinol 1:44–53
3. Park MH, Falconer C, Viner RM, Kinra S (2012) The impact of childhood obesity on morbidity and mortality in adulthood: a systematic review. Obes Rev 13(11):985–1000
4. Reilly JJ, Kelly J (2011) Long-term impact of overweight and obesity in childhood and adolescence on morbidity and premature mortality in adulthood: systematic review. Int J Obes 35(7):891–898
5. Al-Mulhim AS, Al-Hussaini HA, Al-Jalal BA, Al-Moagal RO, Al-Najjar SA (2014) Obesity disease and surgery. Int J Chronic Dis Article ID 652341:9
6. Koning L, Merchant AT, Pogue J, Anand SS (2007) Waist circumference and waist-to-hip ratio as predictors of cardiovascular events: meta-regression analysis of prospective studies. Eur Heart J 28:850–856
7. Rizk NM, Yousef M (2012) Association of lipid profile and waist circumference as cardiovascular risk factors for overweight and obesity among school children in Qatar. Diabetes Metab Syndr Obes 5:425–432
8. Miralles CSW, Wollinger LM, Marin D, Genro JP, Contini V, Morelo Dal Bosco S (2015) Waist-to-height ratio (WHtR) and triglyceride to HDL-c ratio (TG/HDL-c) as predictors of cardiometabolic risk. Nutr Hosp 31(5):2115–2121
9. Millán J, Pintó X, Muñoz A, Zúñiga M, Rubiés-Prat J, Pallardo LF et al (2009) Lipoprotein ratios: physiological significance and clinical usefulness in cardiovascular prevention. Vasc Health Risk Manag 5:757–765
10. Zhu L, Lu Z, Zhu L, Ouyang X, Yang Y, He W et al (2015) Lipoprotein ratios are better than conventional lipid parameters in predicting coronary heart disease in Chinese Han people. Kardiol Pol 73(10):931–938
11. Lemieux I, Lamarche B, Couillard C, Pascot A, Cantin B, Bergeron J et al (2001) Total cholesterol/HDL cholesterol ratio vs LDL cholesterol/HDL cholesterol ratio as indices of ischemic heart disease risk in men: the Quebec Cardiovascular Study. Arch Intern Med 161(22):2685–2692
12. Kastelein JJ, van der Steeg WA, Holme I, Gaffney M, Cater NB, Barter P et al (2008) TNT Study Group; IDEAL Study Group. Lipids, apolipoproteins, and their ratios in relation to cardiovascular events with statin treatment. Circulation 117:3002–3009
13. Sniderman AD (2005) Apolipoprotein B versus non–high-density lipoprotein cholesterol: and the winner is. Circulation 112:3366–3367
14. Chien KL, Hsu HC, Su TC, Chen MF, Lee YT, Hu FB (2007) Apolipoprotein B and non-high density lipoprotein cholesterol and the risk of coronary heart disease in Chinese. J Lipid Res 48(11):2499–2505
15. Soliman HM, Mosaad YO, Ibrahim A (2019) The prevalence and the clinical profile of metabolic syndrome in children and adolescents with Type 1 diabetes. Diabetes Metab Syndr 13:1723–1726
16. Zheng S, Shi S, Ren X, Han T, Li Y, Chen Y et al (2016) Triglyceride glucose-waist circumference, a novel and effective predictor of diabetes in first-degree relatives of type 2 diabetes patients: cross-sectional and prospective cohort study. J Transl Med 14(1):260
17. Lim J, Kim J, Koo SH, Kwon GC (2019) Comparison of triglyceride glucose index, and related parameters to predict insulin resistance in Korean adults: An analysis of the 2007-2010 Korean National Health and Nutrition Examination Survey. PLoS ONE 14(3):e0212963
18. Egyptian Growth charts. Diabetes Endocrine & Metabolic Pediatric Unit and National Research Center Cairo, in collaboration with Wright State University. School of Medicine Department of Community Health Life Span. Health Research Center (2002).
19. Aggarwal J, Reddy S, Nagtilak S (2014) Evaluation of non-HDL-cholesterol/HDL-cholesterol ratio as a predictor of coronary artery disease. IJAR 2(5):277–283
20. Matthews DR, Hosker JR, Rudenski AS, Naylor BA, Treacher DF, Turner RC (1985) Homeostasis model assessment: insulin resistance and fl-cell function from fasting plasma glucose and insulin concentrations in man. Diabetologia 28:412–419
21. Keskin M, Kurtoglu S, Kendirci M, Atabek ME, Yazici C (2005) 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 115:e500–e503
22. Guerrero-Romero F, Simental-Mendía LE, González-Ortiz M, Martínez-Abundis E, Ramos-Zavala MG, Hernández-González SO et al (2010) The product of triglycerides and glucose, a simple measure of insulin sensitivity. Comparison with the euglycemic-hyperinsulinemic clamp. J Clin Endocrinol Metab 95:3347–3351
23. Carr MC, Brunzell JD (2004) Abdominal obesity and dyslipidemia in the metabolic syndrome: importance of type 2 diabetes and familial combined hyperlipidemia in coronary artery disease risk. J Clin Endocrinol Metab 89(6):2601–2607
24. Raj M (2012) Obesity and cardiovascular risk in children and adolescents. Indian J Endocrinol Metab 16(1):13–19
25. Ugwuja EI, Ogbonna NC, Nwibo AN, Onimawo IA (2013) Overweight and obesity, lipid profile and atherogenic indices among civil servants in Abakaliki, South Eastern Nigeria. Ann Med Health Sci Res 3(1):13–18
26. Reinehr T, De SG, Toschke AM, Andler W (2006) Long-term follow-up of cardiovascular disease risk factors in children after an obesity intervention. Am J Clin Nutr 84(3):490–496
27. Szczygielska A, Widomska S, Jaraszkiewicz M, Knera P, Muc K (2003) Blood lipids profile in obese or overweight patients. Ann Univ Mariae Curie Sklodowska Med 58(2):343–349
28. Bhatti MS, Akbri MZ, Shakoor M (2001) Lipid profile in obesity. J Ayub Med Coll Abbottabad 13(1):31–33
29. Guh DP, Zhang W, Bansback N, Amarsi Z, Birmingham CL, Anis AH (2009) The incidence of co-morbidities related to obesity and overweight: a systematic review and meta-analysis. BMC Public Health 9:88
30. Hussain A, Hydrie MZ, Claussen B, Asghar S (2010) Type 2 diabetes and obesity: A review. J diabetol 2:1
31. Freemantle N, Holmes J, Hockey A, Kumar S (2008) How strong is the association between abdominal obesity and the incidence of type 2 diabetes? Int J Clin Pract 62(9):1391–1396
32. Levy-Marchal C, Arslanian S, Cutfield W, Sinako A, Druet C, Marcovecchio ML et al (2010) Insulin resistance in children: consensus, perspective, and future directions. J Clin Endocrinol Metab 95:5189–5198
33. Ten S, Maclaren N (2004) Insulin resistance syndrome in children. J Clin Endocrinol Metab 89:2526–2539
34. Hajian-Tilaki K, Heidari B (2015) Is waist circumference a better predictor of diabetes than body mass index or waist-to-height ratio in Iranian adults? Int J Prev Med 6(1):5
35. Jamar G, de Almeida FR, Gagliardi A, Sobral MR, Ping CT, Sperandio E (2017) Evaluation of waist-to-height ratio as a predictor of insulin resistance in non-diabetic obese individuals. A cross-sectional study. Sao Paulo Med J 135(5):462–468
36. Dou Y, Jiang Y, Yan Y, Chen H, Zhang Y, Chen X et al (2020) Waist-to-height ratio as a screening tool for cardiometabolic risk in children and adolescents: a nationwide cross-sectional study in China. BMJ open 10(6):e037040
37. Bojanic D, Ljubojevic M, Krivokapic D, Gontarev S (2020) Waist circumference, waist-to-hip ratio, and waist-to-height ratio reference percentiles for abdominal obesity among Macedonian adolescents. Nutr Hosp 27 37(4):786–793
38. Ghouili H, Ouerghi N, Ben Khalifa W, Boughalmi A, Dridi A, Gmada N et al (2020) First reference curves of waist circumference and waist-to-height ratio for Tunisian children. Arch Pediatr 27(2):87–94