World Academy of Science, Engineering and Technology
International Journal of Medical and Health Sciences
Vol:17, No:9, 2023

The Relationship between Anthropometric Obesity Indices and Insulin in Children with Metabolic Syndrome

Mustafa M. Donma, Orkide Donma

***Abstract*—** The number of indices developed for the evaluation of obesity and metabolic syndrome (MetS) both in adults and pediatric population is ever increasing. These indices can be weight-dependent or weight–independent. Some are extremely sophisticated equations and their clinical utility is questionable in routine clinical practice. The aim of this study was to compare presently available obesity indices and find the most practical one. Their associations with MetS components were also investigated to determine their capacities in differential diagnosis of morbid obesity with and without MetS. Children with normal body mass index (N-BMI) and morbid obesity were recruited for this study. Three groups were constituted. Age- and sex-dependent BMI percentiles for morbid obese (MO) children were above 99 according to World Health Organization tables. Of them, those with MetS findings were evaluated as MetS group. Children, whose values were between 85 and 15, were included in N-BMI group. The study protocol was approved by the Ethics Committee of Tekirdag Namik Kemal University, Faculty of Medicine. Parents filled out informed consent forms to participate in the study. Anthropometric measurements and blood pressure values were recorded. BMI, hip index (HI), conicity index (CI), triponderal mass index (TPMI), body adiposity index (BAI), body shape index (BSI), body roundness index (BRI), abdominal volume index (AVI), waist-to-hip ratio (WHR) and [waist circumference (WC) + hip circumference (HC)]/2 were the formulas examined in this study. Routine biochemical tests including fasting blood glucose (FBG), insulin (INS), blood lipids were performed. Statistical program SPSS was used for the evaluation of study data; $p < 0.05$ was accepted as the statistical significance degree. HI did not differ among the groups. A statistically significant difference was noted between N-BMI and MetS groups in terms of ABSI. All the other indices were capable of making discrimination between N-BMI-MO, N-BMI- MetS and MO-MetS groups. No correlation was found between FBG and any obesity indices in any groups. The same was true for INS in N-BMI group. Insulin was correlated with BAI, TPMI, CI, BRI, AVI and (WC+HC)/2 in MO group without MetS findings. In the MetS group, the only index, which was correlated with INS, was (WC+HC)/2. These findings have pointed out that complicated formulas may not be required for the evaluation of the alterations among N-BMI and various obesity groups including MetS. The simple easily computable weight-independent index, (WC+HC)/2, was unique, because it was the only index, which exhibits a valuable association with INS in MetS group. It did not exhibit any correlation with other obesity indices showing associations with INS in MO group. It was concluded that (WC+HC)/2 was pretty valuable practicable index for the discrimination of MO children with and without MetS findings.

***Keywords*—**Fasting blood glucose, insulin, metabolic syndrome, obesity indices.

M. M. D. is with the Tekirdag Namik Kemal University, Faculty of Medicine, Department of Pediatrics, Tekirdag, Turkey (corresponding author, phone: 00-90-532-371-72-07; fax: 00-90-282-250-99-28; (e-mail: mdonma@gmail.com).

O. D. Prof. Dr.(retd) is with the Istanbul University-Cerrahpasa, Cerrahpasa Medical Faculty, Department of Medical Biochemistry, Istanbul, Turkey (e-mail: odonma@gmail.com).

I. Introduction

VARIOUS stages of obesity require the detailed investigation of metabolic alterations including insulin resistance. The late stage of obesity is described as morbid obesity (MO) and it commonly leads to a health problem, metabolic syndrome (MetS), characterized by a spectrum of metabolic derangements. [1] For the careful examination of these health problems, anthropometric measurements such as waist circumference (WC) or hip circumference (HC) and the distribution of body's fat compartments such as trunk fat, leg fat or arm fat are generally considered. In some cases, they may not be sufficient. For the purpose, researchers try to develop new obesity indices to make the discriminations between the different stages of obesity and/or obesity-related diseases. There are many weight-based measures and fat distribution-based measures for the screening of adulthood and childhood adiposity [2]-[13]. These indices lie in the line extending from simple equations to sophisticated formulas. Obesity indices may be roughly classified into two categories: Anthropometry-based and fat-based. They are compared in many studies performed on the matter [2]-[13].

Within the scope of anthropometry-based indices, there are formulas using weights of the individuals. However, in the other group of formulas, weight parameter is not used.

BMI, CI, TPMI, BSI, HI are some examples to such indices using weight. On the other hand, BAI, BRI, AVI, WHR, (WC+HC)/2 are the indices, which do not include weight parameter.

The most frequently used anthropometric measurements are WC and HC. Since both anthropometric measurements increase steadily as the severity of obesity increases, it was thought that (WC+HC)/2 may be introduced as a new obesity marker to be used in routine clinical practices. This was confirmed in a previous report [14].

This study was focused on anthropometry-based obesity indices. Weight-dependent and weight-independent anthropometry-based indices were considered. The profile of each index is examined in N-BMI, MO and MetS groups. Besides, their associations with FBG, triglycerides (TRG), high density lipoprotein cholesterol (HDL-C) and insulin (INS) were checked. Finally, TRG/HDL-C was also examined.

II. Patients and Methods

A. Patients

167 children were included in this study. Three groups were constituted. The first group was composed of 35 children with N-BMI. Children in this group were between 15^{th} and 85^{th} age- and sex-dependent BMI percentiles according to the tables prepared by World Health Organization (WHO) [15]. Second group comprised 96 MO children. Their percentiles were above 99. The same was true for the third group. However, in this group, the children, besides being MO, had at least two MetS components. The second and third groups were indicated as MO+MetS- and MO+MetS+, respectively.

MetS criteria were listed in the study group [16]. In MetS group, children must exhibit blood pressure values, either systolic blood pressure (SBP) or diastolic blood pressure, above 130 mm Hg or 85 mm Hg, respectively. The second criteria were the elevations well above 100 mg/dl in FBG values. Third criteria were related to lipid parameters TRG and HDL-C. Increased TRG (150 mg/dl) or decreased HDL-C (40 mg/dl) must be present as one of MetS components.

Informed consent forms were taken from the parents of the children. Institutional Ethical Committee for Non-Interventional Clinical Studies confirmed the study protocol.

B. Anthropometric Measurements and Weight-Dependent as Well as Weight-Independent Ratios

Weight, height, WC, HC, neck circumference and head circumference values were measured and recorded.

Within the scope of ratios, BMI, CI, TPMI, ABSI, HI as weight-dependent, BAI, BRI, AVI, WHR, (WC + HC)/2 as weight-independent ratios were calculated.

C. Determination of MetS Components

Blood pressure measurements were performed. Values obtained for SBP and diastolic blood pressure were recorded.

FBG, INS, TRG, HDL-C concentrations were determined. TRG-to HDL-C ratio was calculated.

D. Statistical Evaluation of the Study Data

Statistical evaluation of the obesity index formulas as well as biochemical parameters in groups was performed. The statistical software SPSS was used for the evaluation of the data. Mean and SD values were computed. Due to the availability of three groups, analysis of variance F-test was performed to determine possible statistically significant differences among the groups. Correlation analyses were performed and plots for linear regression were drawn.

III. Results

Names, abbreviations and the equations of the formulas used within the scope of the study are listed in Table I.

BMI, WC/HC, WHtR, (WC+HC)/2, TPMI were the easily calculable ratios/indices. All the others were of sophisticated formulas, which require complex mathematical procedures.

TABLE I
Formulas of Obesity Indices

Abbr.	NAME	Equation
BMI	body mass index	$weight/ (height)^2$
WHR	waist C-to-hip C ratio	WC/HC
WHtR	waist C-to-height ratio	WC/Ht
(WC+HC)/2	(WC+HC)/2	(WC+HC)/2
HI	hip index	$HC*weight^{-0.482} * height^{0.310}$
CI	conicity index	$WC/0.109 * \sqrt{(weight/height)}$
TPMI	triponderal mass index	$weight/height^{3}$
BAI	body adiposity index	$HC/height^{0.8}$
ABSI	body shape index	$1000 * WC*weight^{-2/3} *height^{5/6}$
BRI	body roundness index	$364.2 - 365.5 * (1-((0.5 * WC/ \pi)^2$
AVI	abdominal volume index	$(2 * (WC*100)^2 + 0.7 * (WC*100- HC*100)^2)/1000$

C = circumference.

Mean value±SD and the p values as the statistical significance degrees calculated for determining the possible differences among obesity indices values calculated for the groups are shown in Table II.

Hip index values were calculated for N-BMI, MO and MetS groups. No statistically significant difference was observed among the groups. Considering ABSI values, it was observed that the differences between N-BMI and MO groups as well as MO and MetS groups were statistically insignificant ($p > 0.05$). However, there was a statistically significant difference between N-BMI and MetS groups ($p < 0.01$). Statistically significant differences were detected among the groups in terms of all of the remaining formulas. The p values for N-BMI and MetS as well as N-BMI and MO comparisons were 0.001. The p values for the difference between MO and MetS groups are shown in Table II.

TABLE II
Significance among Groups for Obesity Indices (mean ± SD)

Parameter	N-BMI Group 1	MO Group 2	MetS Group 3
BMI#	17.6 ± 2.8	27.4 ± 5.9	30.6 ± 8.1
WHR#	0.82 ± 0.06	0.90 ± 0.05	0.95 ± 0.17
WHtR#	0.44 ± 0.04	0.60 ± 0.06	0.65 ± 0.12
(WC+HC)/2 ϕ	69.5 ± 10.5	91.9 ± 15.5	101.2 ± 17.8
HI NS	0.152 ± 0.007	0.154 ± 0.005	0.154 ± 0.006
CI ϕ	1.14 ± 0.06	1.27 ± 0.07	1.34 ± 0.24
TPMI#	12.4 ± 1.5	18.7 ± 2.3	20.2 ± 4.4
BAI#	57.1 ± 4.3	71.5 ± 6.4	74.8 ± 7.5
ABSI NS	77.5 ± 4.0	79.9 ± 4.4	83.3 ± 15.4
BRI ϕ	2.28 ± 0.68	5.46 ± 1.27	7.02 ± 4.38
AVI*	8.2 ± 2.4	15.7 ± 5.5	20.6 ± 11.5

N = normal, Height = Ht, WHtR = waist-to-height ratio, BSI = body shape index, NS = not significant; [* 2-3 < 0.001, ϕ 2-3 < 0.01, # 2-3 < 0.05].

Table III shows the mean ± SD values for some physiological and biochemical parameters, which are important in both obesity and MetS. Figs. 1 and 2 show the linear regression plots for correlation analyses.

Significant correlations between the anthropometric ratio; (WC+HC)/2 and INS in both MO+MetS- ($r = 0.380$; $p < 0.001$) and MO+MetS+ ($r = 0.449$; $p < 0.01$) groups were observed.

TABLE III
SOME PHYSIOLOGICAL AND BIOCHEMICAL PARAMETERS (MEAN ± SD)

Parameter		N-BMI Group 1	MO Group 2	MetS Group 3
SBP *	mm.Hg	107 ± 11	116 ± 14	133 ± 15
DBP *	mm Hg	67 ± 12	74 ± 10	87 ± 14
FBG NS	mg/dl	90 ± 9	90 ± 7	94 ± 7
TRG *	mg/dl	74 ± 25	109 ± 56	178 ± 119
HDL-C ϕ	mg/dl	66 ± 21	51 ± 12	45 ± 13
TRG/HDL-C *	mIU/L	1.3 ± 0.7	2.5 ± 2.3	4.6 ± 3.9
INS #	mIU/L	10.3 ± 8.4	20.4 ± 18.8	24.3 ± 12.4

N = normal, DBP = diastolic blood pressure, HDL-C = high density lipoprotein-cholesterol, NS = not significant; [* 1-2, 1-3, 2-3 < 0.05, ϕ 1-2, 1-3 0.001, # 1-2, 1-3 0.01].

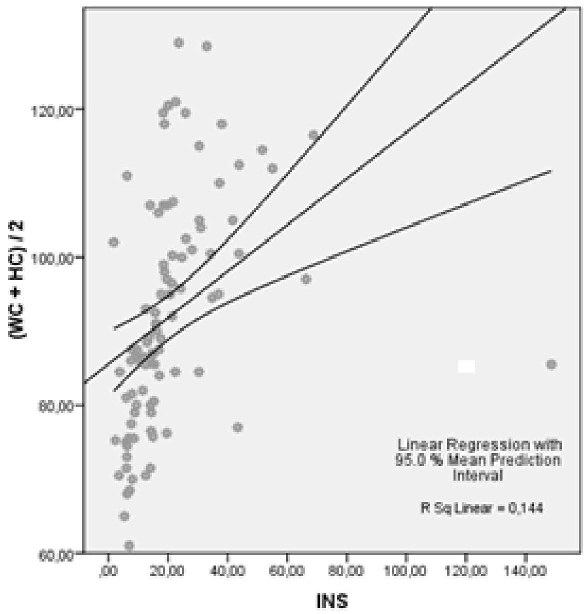

Fig. 1 Correlation between (waist circumference + hip circumference)/2 and INS in MO group

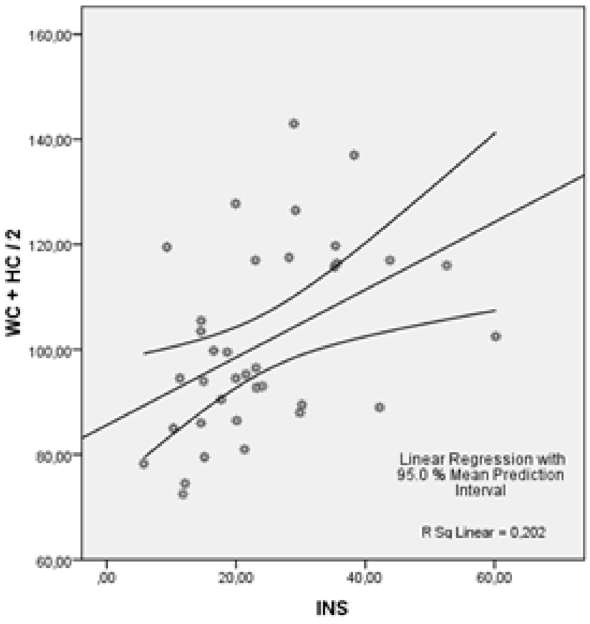

Fig. 2 Correlation between (waist circumference + hip circumference)/2 and INS in MetS group

IV. DISCUSSION

Obesity is associated with many chronic diseases. Metabolic alterations in obesity have the potential to develop hypertension, MetS, diabetes mellitus, cardiovascular diseases and malignancies [2]-[8], [13], [17]-[20]. Therefore, formulas created for the adequate interpretation of obesity, are not only available for the discrimination of various stages of this disease, but also give useful information during the courses of the above-mentioned diseases. Particularly, it has been shown that some of these formulas, which are collectively known as "obesity indices", exhibit meaningful associations with cardiometabolic risk factors. Studies were performed to find the best anthropometric index, which is both simple and suitable for obesity studies [2]-[14], [21]-[24].

Of these indices, BRI was introduced as the indicator of cardiometabolic risk [25]. TPMI was included in discriminating central obesity and hypertension in overweight adolescents [26]. In a report, individuals with elevated ABSI consistently exhibited higher risk of death compared to those with low-ABSI [27].

As known, obesity is a risk factor for diabetes. Within this context, CI, AVI, BRI, CMI were reported as alternative indexes for diabetes prediction. BRI possesses higher discriminatory power for this purpose compared to the performance of WC [28].

A temporal association was noted between TPMI and blood pressure values in children. Higher TPMI predicted higher subsequent BP [29]. The prevalence of cardiometabolic risks increased with the severity of obesity. The risk of MetS also increased with the severity of obesity. Since TPMI reflected the severity of obesity and predicted the risk of MetS and its components, clinical applications of this index may help the identification of the childhood obesity and MetS [30]. In Iranian preschool children, TPMI was reported as a predictor for obesity [31]. Obesity, as classified by TPMI, was strongly associated with several cardiovascular risk factors in Brazilian adolescents [32]. CI had the best ability to identify diabetes [33].

In this respect, some biochemical parameters, such as FBG, INS, TRG, HDL-C as well as some ratios, gain importance in terms of associations between obesity indices and these biochemical parameters due to their links with glucose and lipid homeostasis. These parameters are both considered MetS components and also considered within the scope of cardiometabolic risk factors.

In a previous study, INS was introduced as the only parameter, which showed statistically significant difference between MO-MS2, MO-MS3 and MS2-MS3. It was then concluded that FBG may be replaced by INS as one of the MetS components [1].

In our study, (WC+HC/2) was the simplest formula, which showed the most prominent behavior in term of the difference between MO and MetS groups. The correlation was not found between INS and (WC+HC)/2 in N-BMI group. Correlations were r = 0.380 and r = 0.449; p < 0.01 in MO and MetS groups, respectively. In MetS groups, higher correlation was present. The lack of correlations between FBG and (WC+HC)/2 in all three groups emphasized the clinical utility of INS parameter in this discussion.

Another important point in MetS group was the correlation observed between INS and diastolic blood pressure, which was absent in other groups.

A third point was the correlation between INS and HDL-C. The only group, which exhibited significant correlation between these two parameters was MetS group. This finding along with the previous one emphasized the evaluation of INS parameter among children with MetS findings.

In MetS group, INS was correlated with an anthropometric obesity index, a physiological finding and a biochemical parameter, which is commonly considered as cardiometabolic risk factor.

References

[1] M. Donma, and O. Donma, “Associations between surrogate insulin resistance indices and the risk of metabolic syndrome in children,” *Int. J. Med. Health. Sci.,* vol. 14, no. 2, pp. 61- 64, 2020.

[2] A. Basit, N. Mustafa, N. Waris, S. Askari, A. Fawwad, and NDSP members, “Predicting the risk of type 2 diabetes through anthropometric indices in Pakistani adults- A sub-analysis of second national diabetes survey of Pakistan 2016-2017 (NDSP-07),” *Diabetes Metab. Syndr.,* vol. 15, no. 2, pp. 543-547, Mar-Apr 2021.

[3] S. N. Darko, K. A. C. Meeks, W. K. B. A. Owiredu, E. F. Laing, D. Boateng, E. Beune, J. Addo, A. de-Graft Aikins, S. Bahendeka, F. Mockenhaupt, J. Spranger, P. Agyei-Baffour, K. Klipstein-Grobusch, L. Smeeth, C. Agyemang, and E. Owusu-Dabo, “Anthropometric indices and their cut-off points in relation to type 2 diabetes among Ghanaian migrants and non-migrants: The RODAM study,” *Diabetes Res. Clin. Pract.,* vol. 173, pp. 108687, Mar. 2021.

[4] J. V. Chávez-Sosa, R. Rojas-Humpire, R. Gutierrez-Ajalcriña, and S. Huancahuire-Vega, “Association between lifestyles, anthropometric measurements and peripheral arterial disease in public sector health workers,” *Am. J. Cardiovasc. Dis.,* vol. 11, no. 2, pp. 194-202, Apr. 2021.

[5] B. Zhang, Y. Fan, Y. Wang, L. Zhang, C. Li, J. He, P. Guo, M. Zhang, and M. Zhang, “Comparison of bioelectrical body and visceral fat indices with anthropometric measures and optimal cutoffs in relation to hypertension by age and gender among Chinese adults,” *BMC Cardiovasc. Disord.,* vol. 21, no. 1, pp. 291, Jun. 2021.

[6] Q. Song, T. Huang, J. Song, X. Meng, C. Li, Y. Wang, and H. Wang, “Causal associations of body mass index and waist-to-hip ratio with cardiometabolic traits among Chinese children: A Mendelian randomization study,” *Nutr. Metab. Cardiovasc. Dis.,* vol. 30, no. 9, pp. 1554-1563, Aug.2020.

[7] W. Albaker, S. El-Ashker, M. A. Baraka, N. El-Tanahi, M. Ahsan, and M. Al-Hariri, “Adiposity and cardiometabolic risk assessment among university students in Saudi Arabia,” *Sci. Prog.,* vol. 104, no. 1, pp. 36850421998532, Jan-Mar 2021.

[8] I. Kishimoto, “Trunk-to-leg fat ratio-An emerging early marker of childhood adiposity, and future cardiometabolic risks,” *Circ. J.,* vol. 80. no. 8, pp. 1707-1709, Jul. 2016.

[9] M. Donma, O. Donma, M. Aydin, M. Demirkol, B. Nalbantoglu, A. Nalbantoglu, and B. Topcu, “Gender differences in morbid obese children: Clinical significance of two diagnostic obesity notation model assessment indices,” *Int. J. Med. Health Sci.,* vol. 10, no. 5, pp. 310 – 316, May 2016.

[10] O. Donma, and M. Donma, “Evaluation of the weight-based and fat-based indices in relation to basal metabolic rate-to-weight ratio,” *Int. J. Med. Health Sci.,* vol. 13, no. 5, pp. 214-218, May 2019.

[11] A. Oliver Olid, L. Martín López, J. M. Moreno Villares, M. Á. Martínez González, V. de la O Pascual, and N. Martín Calvo, “Validation of the anthropometric data reported by parents of participants in the SENDO project,” *Nutr. Hosp.,* 2021 Aug 25. Spanish. Epub ahead of print.

[12] H. K. Tang, C. T. C. Nguyen, and N. H. T. Vo, “Anthropometric indicators to estimate percentage of body fat: A comparison using cross-sectional data of children and adolescents in Ho Chi Minh City, Vietnam,” *Indian J. Pediatr.,* 2021 Sep 13. Epub ahead of print.

[13] M. Mahdavi-Roshan, A. Rezazadeh, F. Joukar, M. Naghipour, S. Hassanipour, and F. Mansour- Ghanaei, “Comparison of anthropometric indices as predictors of the risk factors for cardiovascular disease in Iran: The PERSIAN Guilan Cohort Study,” *Anatol. J. Cardiol.,* vol. 25, no. 2, pp. 120-128, Feb. 2021.

[14] M. Donma, and O. Donma, “An obesity index derived from waist and hip circumferences well-matched with other indices in children with obesity,” *Int. J. Med. Health Sci.,* vol. 16, no. 10, pp. 152 – 155, 2022.

[15] WHO World Health Organization (WHO). The WHO child growth standards. 2016 June. Access: http://www.who.int/childgrowth/en/

[16] P. Zimmet, K. G. Alberti, F. Kaufman, N. Tajima, M. Silink, S. Arslanian, G. Wong, P. Bennet, J. Shaw, S. Caprio, and IDF consensus group, “The metabolic syndrome in children and adolescents-an IDF consensus report,” *Pediatr. Diabetes,* vol. 8, no. 5, pp. 299-306, 2007.

[17] M. Litwin, and Z. Kułaga, “Obesity, metabolic syndrome, and primary hypertension,” *Pediatr. Nephrol.,* vol. 36, no.4, pp. 825-837, Apr. 2021.

[18] G. Katamba, A. Musasizi, M. A. Kinene, A. Namaganda, and F. Muzaale, “Relationship of anthropometric indices with rate pressure product, pulse pressure and mean arterial pressure among secondary adolescents of 12-17 years,” *BMC Res. Notes.,* vol. 14, no. 1, pp. 101, Mar. 2021.

[19] S. Weihrauch-Blüher, P. Schwarz, and J. H. Klusmann, “Childhood obesity: increased risk for cardiometabolic disease and cancer in adulthood,” *Metabolism.,* vol. 92, pp.147-152, Mar. 2019.

[20] I. C. Lega, and L. L. Lipscombe, “Review: Diabetes, obesity, and cancer-pathophysiology and clinical implications,” *Endocr. Rev.,* vol. 1, no. 41(1), pp. bnz014, Feb. 2020.

[21] D. Pasanta, K. T. Htun, J. Pan, M. Tungjai, S. Kaewjaeng, S. Chancharunee, S. Tima, H. J. Kim, J. Kæwkhao, and S. Kothan, “Waist circumference and BMI are strongly correlated with MRI-derived fat compartments in young adults,” *Life (Basel).,* vol. 11, no. 7, pp. 643, Jul. 2021.

[22] X. F. Ye, W. Dong, L. L. Tan, Z. R. Zhang, Y. L. Qiu, and J. Zhang, “Identification of the most appropriate existing anthropometric index for home-based obesity screening in children and adolescents,” *Public Health.,* vol. 189, pp. 20-25, Dec. 2020.

[23] S. Cho, A. Shin, J. Y. Choi, S. M. Park, D. Kang, and J. K. Lee, “Optimal cutoff values for anthropometric indices of obesity as discriminators of metabolic abnormalities in Korea: results from a Health Examinees study,” *BMC Public Health.,* vol. 21, no. 1, pp. 459, Mar. 2021.

[24] F. L. Zhang, J. X. Ren, P. Zhang, H. Jin, Y. Qu, Y. Yu, Z. N. Guo, and Y. Yang, “Strong association of waist circumference (WC), body mass index (BMI), waist-to-height ratio (WHtR), and waist-to-hip ratio (WHR) with diabetes: A population-based cross-sectional study in Jilin Province, China,” *J. Diabetes Res.,* vol. 2021, pp. 8812431, May 2021.

[25] J. Xu, L. Zhang, Q. Wu, Y. Zhou, Z. Jin, Z. Li, and Y. Zhu, “Body roundness index is a superior indicator to associate with the cardio-metabolic risk: evidence from a cross-sectional study with 17,000 Eastern-China adults,” *BMC Cardiovasc. Disord.,* vol. 21, no. 1, pp. 97, Feb. 2021.

[26] A. E. Malavazos, G. Capitanio, V. Milani, F. Ambrogi, I. A. Matelloni, S. Basilico, C. Dubini, F. M. Sironi, E. Stella, S. Castaldi, F. Secchi, L. Menicanti, G. Iacobellis, M. M. Corsi Romanelli, M. O. Carruba, and L. F. Morricone, “Tri-ponderal mass index vs body mass index in discriminating central obesity and hypertension in adolescents with overweight,” *Nutr. Metab. Cardiovasc. Dis.,* vol. 31, no. 5, pp. 1613-1621, May 2021.

[27] S. Christakoudi, K. K. Tsilidis, and D. C. Muller, “A body shape index (absi) achieves better mortality risk stratification than alternative indices of abdominal obesity: results from a large European cohort,” *Sci. Rep.,* vol. 10, pp. 14541, 2020.

[28] Z. Wang, S. He, and X. Chen, “Capacity of different anthropometric measures to predict diabetes in a Chinese population in southwest China: a 15-year prospective study,” *Diabet. Med.* vol. 36, no. 10, pp. 1261-1267, 2019.

[29] Y. Cui, F. Zhang, H. Wang, L. Zhao, R. Song, M. Han, and X. Shen, “Temporal associations between tri-ponderal mass index and blood pressure in chinese children: a cross- lag analysis,” *Nutrients.,* vol. 24, no. 14(9), pp. 1783, Apr. 2022.

[30] Y. J. Seo, Y. S. Shim, and, H. S. Lee, “Metabolic risk assessment in children and adolescents using the tri-ponderal mass index,” *Sci. Rep.,* vol. 12, pp. 10094, 2022.

[31] F. Mardali, M. Naziri, M. H. Sohouli, S. Fatahi, F. Sadat Hosseini-Baharanchi, M. A. Găman, and F. Shidfar. “Predictors of central and general obesity in iranian preschool children: which anthropometric indices can be used as screening tools?,” *BMC Pediatr.,* vol. 31, no. 22(1), pp. 320, May. 2022.

[32] R. O. Alvim, J. H. Siqueira, D. Zaniqueli, N. S. Paiva, M. P. Baldo, K. V. Bloch, and J. G. Mill, "Reference values for the tri-ponderal mass index and its association with cardiovascular risk factors in Brazilian adolescents aged 12 to 17 years," *Nutrition.,* vol. 99-100, pp. 111656, Jul-Aug. 2022.

[33] X. C. Liu, Y. S. Liu, H. X. Guan, Y. Q. Feng, and J. Kuang, "Comparison of six anthropometric measures in discriminating diabetes: a cross-sectional study from the national health and nutrition examination survey," *J. Diabetes.,* vol. 14, no. 7, pp. 465-475, Jul. 2022.