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Anthropometric indicators as predictors of the risk of metabolic syndrome in adult working men

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Abstract: Measurement of body weight, height, waist and hip circumference is a standard procedure that allows to better define the risk of metabolic syndrome.
The aim of the study is to determine the usefulness of anthropometric indicators such as BMI, WC (waist circumference), WHR, WHtR and percentage of body fat to predict the metabolic cardiovascular risk in the adult male population of Krakow, as well as an attempt to determine the metabolic cardiovascular risk with the original anthropometric risk index.
The study included 405 men from the population working in the T. Sendzimir Steelworks in Kraków at the age of 30–69 years. Anthropometric measurements: body height measured to the nearest mm, circuits (waist, hips) measured to the nearest centimetre, the percentage of fat (the type of electronic scales Tanita BF 300) measured according to the standard protocol by the same technician and biomedical indicators assessing the functional status of organism, total cholesterol, HDL, LDL, triglycerides, glucose and blood pressure measured with a mercury manometer.
As a measure of goodness of fit for the indices of risk (and their components), the AUC method was used for the ROC curves to evaluate the sensitivity and specificity of the diagnostic test.
The results show that significant in predicting the risk of metabolic syndrome are not only standard anthropometric measurements specified in the standards of WHO, EGIR, NCEP and IDF. In addition, it is important to take into account the amount of fat and calculate the cumulative risk index based on all relevant measurements and indicators.

Key words: metabolic syndrome, BMI, WHR, cholesterol, blood pressure, men

Introduction

The increasing prevalence of obesity is one of the risk factors of metabolic cardiovascular diseases, including hypertension and diabetes mellitus type II. Numerous studies conducted over the past few decades have identified risk fac-

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tors responsible for cardiovascular disease, which is one of the main causes of death and disability for men in Western countries, including Poland (Tatoń et al. 2006). WHO recommends the use of BMI (body mass index) to identify overweight and obesity in the general population (Alberti and Zimmet 1998). Measuring abdominal obesity, such as waist circumference or WHR (waist-to-hip index), proved to be more accurate in predicting the risk of cardiovascular disease, and have replaced some of the definitions of BMI in the clinical diagnosis of the metabolic syndrome (Zimmet et al. 2005b, Lee et al. 2008). Recent studies on the utility of the indicator TG/HDL ratio (triglicerides to high-density lipoproteid) as a measure of insulin resistance suggest its usefulness in epidemiological studies of hypertension, kidney disease and other risk factors for cardio-metabolic disease (Salazar et al. 2012). Metabolic syndrome (MS) is known for almost 50 years, but its many definitions do not facilitate proper diagnosis and prevention (Bauduceau et al. 2007).

Metabolic syndrome has also been called insulin resistance syndrome and has a multidimensional nature, hence, there are many definitions of it in the literature (Tatoń et al. 2006, Huang 1998). It is directly related to the presence of android type of obesity, which can lead to insulin resistance and underlying the early diagnosis of type II diabetes. The metabolic syndrome, including abdominal obesity and insulin resistance, is a primary precursor of all the risk factors of cardiovascular disease and the predictor type II diabetes (Bauduceau et al. 2007).

The aim of the study was to determine the usefulness of anthropometric indicators such as BMI, WC (waist circumference), WHR, WHtR (waist to height ratio) and the percentage of body fat to predict the cardiovascular-metabolic risk in adult male population of Krakow, as well as an attempt to determine the risk of cardio-metabolic syndrome with the original ratio defined as the anthropometric risk index. The use of overall risk index of metabolic syndrome allows for more efficient and accurate selection of men at risk.

Material and methods

In 2001, the Department of Anthropology, University of Physical Education, Krakow, in cooperation with the Department of Health Care "Medical Center-Nowa Huta" Sp. z o.o. held a medical surveillance of workers of T. Sendzimir Steelworks in Krakow. The aim of the collaboration was to implement a research program on the physical condition of the adult population of Krakow. The research covered a group of 838 men aged 20–70 years, employed in the steelworks in Krakow, representing the community of industrial workers in the Krakow's population.

The following characteristics were used as measured by the team of researchers: body height measured to the nearest mm, circuits (waist, hips) measured to the nearest centimetre, mass and percentage of fat (BF%) (electronic scales type TANITA BF 300) measured according to the standard protocol, by the same technique.

BMI was calculated as weight (kg) divided by height squared (m2). WHR was calculated as the ratio of waist to hip circumference (expressed in the same units). WHtR ratio was calculated as the ratio of waist size (cm) to the body height (cm).

The biomedical body used the results of laboratory blood tests of the patients (total cholesterol, HDL, LDL, triglycerides, glucose) and pressure levels measured using a mercury manometer as parameters to evaluate the functional status.

Biomedical parameters were read from medical records. In addition, for every man, all kinds of reported diseases or medical problems that occurred in the past were recorded. Further analysis used information on the treatment of cardiovascular disease, hypertension and diabetes. All of these data were received for 405 men, and these were subjected to further analysis. Among them, 99 were diagnosed with TMS (true metabolic syndrome).

All respondents were divided into categories based on several criteria:

1. according to BMI: norm – less than 25 kg/m^2; overweight – between 25 and 30 kg/m^2; obesity – greater or equal 30 kg/m^2;
2. WHR: norm – less than 0.90; increased level – between 0.9 and 1.0; android type of obesity – greater or equal 1.0;
3. WHtR: norm – less than 0.50; increased level – greater or equal 0.50;
4. waist circumference: norm – less than 94 cm; increased level – between 94 and 102 cm; high – greater or equal 102 cm;
5. percentage of fat: norm – between 8 and 20 percent; increased – greater than 20 percent;
6. TG/HDL standard – less than 3.5; increased level – greater or equal 3.5 (Salazar et al. 2012).
7. TG, blood glucose level and blood pressure in accordance with the standard (see Table 1).

Based on the value of anthropometric indices (BMI, WHR, WHtR, WC and BF%) and biomedical indicators (TG/HDL ratio, TG, fasting glucose and blood pressure), the corresponding indices of risk, which is the sum of the number of categories of increased or high level, were calculated. In addition, the overall risk index, which is the sum of the two previous ones, was calculated. Additional risks in each age category were calculated, which allowed the classification into groups of potential risk of metabolic syndrome (possible metabolic syndrome – PMS). Indices were calculated for the following risks:

1. Anthropometric Risk Index (ARI) – as the sum of exceeded standards for criteria 1–5;
2. Biochemical Risk Index (BRI) – as the sum of exceeded standards for criteria 6–7;
3. Overall Risk Index (ORI) – the sum of ARI and BRI.

ORI ≥ 3 was adopted as a criterion for the presence of metabolic syndrome, while conditions ARI ≥ 1 and BRI ≥ 2 being met.

As a measure of goodness of fit for the indices of risk (and their components) the AUC (area under curve) method was used for the ROC (Receiver Operating Characteristics Curves) to evaluate the sensitivity and specificity of the diagnostic test. Sensitivity is the ratio of true positives to the sum of true positives and false negatives, the result gives us information on the proportion of the respondents who had a positive test result. Specificity is the ratio of the true negatives to the sum of true negatives and false positives, letting us know what proportion of the respondents had a negative test result. Stochastic dependencies between the values calculated risk

Table 1. The criteria for metabolic syndrome in men by different standards

	WHO[1]	EGIR [2] (Groupe européen pour l'étude de l'insulinorésistance)	NCEP[3] (United States National Cholesterol Program)	IDF[4] (International Diabetes Foundation)
Year of the development of standards:	1998	1999	2001/2005	2005
applies to:	people with abnormal blood glucose level	only people without diabetes		obese people
The validity criterion:	at least two different criteria	insulin plus at least two different criteria	at least three of the five criteria	at least two different criteria
1. Absolutely required	insulin resistance	hyperinsulinemia		central obesity
2. Obesity (WC or WHR)	WHR > 0.90 or BMI > 30 kg/m^2	WC > 94 cm	WC > 102 cm	WC ≥ 94cm
3. Insulin	not applicable	above the upper quartile for population without diabetes	not applicable	not applicable
4. Dyslipidemia	TG ≥ 1.5 g/l or HDL < 0.35 g/l	TG more than 1.77 g/l or HDL < 0.40 g/l or pharmacologic treatment	TG ≥ 1.5 g/l or pharmacologic treatment	TG > 1.5 g/l or pharmacologic treatment
5. Dyslipidemia (second separate criteria)			< 0.40 g/l	< 0.40 g/l
6. Hyperglycemia	Insulin resistance already required	Insulin resistance already required	Fasting glucose > 1 g/l or pharmacologic treatment	Fasting glucose ≥ 1 g/l or pharmacologic treatment
7. Hypertension	≥ 140/90 mm Hg	≥ 140/90 mm Hg or pharmacologic treatment	> 130 mm Hg systolic or > 85 mm Hg diastolic or pharmacologic treatment	> 130 mm Hg systolic or > 85 mm Hg diastolic or pharmacologic treatment
8. Microalbuminuria	≥ 20 μg/min urinary albumin secretion or albumin-to-creatine ratio ≥ 30mg/g	not applicable		

1 Alberti KG, Zimmet PZ. 1998. Definition, diagnosis and classification of diabetes mellitus and its complications. Part 1: diagnosis and classification of diabetes mellitus provisional report of a WHO consultation. Diabet Med 15: 539–553.

2 Balkau B, Charles MA. 1999. Comment on the provisional report from the WHO consultation: European Group for the Study of Insulin Resistance (EGIR). Diabet Med 16: 442–443,

3 Third Report of the National Cholesterol Education Program (NCEP) expert panel on detection, evaluation and treatment of high blood cholesterol in adults (Adult Treatment Panel III) final report. Circulation 106: 3143–3421.

4 Zimmet P, Alberti KG, Serrano Rios M. 2005a. A new International Diabetes Federation (IDF) worldwide definition of the metabolic syndrome: the rationale and the results. Rev Esp Cardiol 58: 1371–1376.

indices and the diagnosis of the metabolic syndrome in subjects were calculated. GraphPad Prism 4.0 programme was used to calculate the AUC value, Statgraphics 6.0 was used to perform other statistical analysis.

Results

Table 1 shows aggregated values of all anthropometric and biochemical parameters that define the risk of metabolic syndrome in men. Detailed anthropometric characteristics of the respondents are presented in Table 2. Characteristics of biochemical parameters of blood and blood pressure in 405 men undergoing further analysis is given in Table 3.

Anthropological criteria for the allocation of individual indicators and biomedical variables were used to assess the prevalence of increased their categories in the different age groups. Detailed summary is presented in Table 4 and Table 5. For all anthropological indicators, an increase in incidence is observed with age. Mean values obtained for index and risk of cardiovascular disease are presented in Table 6.

Table 3. Characteristics of biochemical parameters and blood pressure of men (N = 405)

Variable	Mean	SD
TG (g/L)	1.85	1.14
HDL (g/L)	1.56	0.52
TG/HDL	1.37	1.14
Glucose (g/L)	0.104	0.013
Systolic BP (mm Hg)	140.98	16.52
Diastolic BP (mm Hg)	91.07	11.29

Table 7 presents detailed results of the sensitivity and specificity of the criteria and risks calculated for indices. The predictive value of the metabolic syndrome in adult working men from Krakow was relatively high (0.8>AUC>0.7) for most variables or anthropometric indicators (BMI, WHtR, waist circumference and percent fat) and risk index (ARI, BRI, ORI) and very high (AUC>0.8) for blood pressure (both: systolic and diastolic). The average value (0.7>AUC>0.6) was obtained for WHR. Poor predictive value (0.5<AUC<0.6) was obtained for the TG, TG/HDL ratio and fasting glucose levels. Taking into account only the indexes of risk, ORI proved to be the most predictive index, although very similar to ARI. BRI (also taking into account blood

Table 2. Anthropometric characteristics of the respondents of all men (N_1 = 838) and a separate group covered by detailed analysis (N_2 = 405)

Variable	Mean	SD	Mean	SD
	N_1=838		N_2=405	
Age [years]	40.78	9.17	46.03	5.98
Height [cm]	174.50	6.465	173.53	6.466
Weight [kg]	79.96	12.949	80.33	12.691
Waist circumference [cm]	90.87	10.631	92.42	10.182
Hip circumference [cm]	99.21	6.796	99.55	6.749
BMI (kg/m^2)	26.23	3.80	26.63	3.66
WHR	0.91	0.072	0.93	0.064
WHtR	0.52	0.061	0.53	0.057
BF% [%]	20.86	6.24	22.08	5.88

N_1 – number of subjects for whom all anthropometric characteristics were measured
N_2 – number of respondents for whom all the biomedical features were measured

Table 4. The incidence of each category of indicators analyzed in adult males (%) (N = 405)

Age	Level	BMI [%]	WHR [%]	WHtR [%]	WC [%]	BF% [%]
30–39.9 N=54	normal	48.15	44.44	44.44	68.52	74.07
	high	37.04	42.59	55.56	18.52	25.93
	low	14.81	12.96	–	12.96	–
40–49.9 N=241	normal	28.82	33.53	28.53	55.88	63.82
	high	54.12	55.88	71.47	29.12	36.18
	low	17.06	10.59	–	15.00	–
50–69.9 N=100	normal	35.00	24.00	16.00	44.00	56.00
	high	47.00	57.00	84.00	34.00	44.00
	low	18.00	19.00		22.00	

Table 5. The incidence of each category of indicators analyzed in adult males (%) (N = 405)

Age	Index level	HDL [%]	TG/HDL [%]	TG [%]	Glucose [%]	Pressure [%]
30–39.9 N=54	normal	34.43	90.74	45.90	100	51.67
	high	31.15	9.26	14.75	0	1.67
	low	34.43	–	39.34	–	46.67
40–49.9 N=241	normal	41.39	93.44	50.82	100	37.38
	high	19.67	6.56	11.07	0	1.97
	low	38.93	–	38.11	–	60.66
50–69.9 N=100	normal	46.00	95.00	43.00	99.00	17.00
	high	17.00	5.00	13.00	1.00	2.00
	low	37.00		44.00		81.00

pressure) adopted an intermediate value between ARI and ORI. Figure 1 shows the ROC curves for the different biochemical variables and blood pressure. The strongest differentiator between healthy individuals and individuals with metabolic syndrome is a systolic blood pressure (AUC=0.98) and diastolic blood pressure (AUC=0.79). Biochemical variables of TG/HDL (AUC=0.57), TG (0.57) and HDL (0.54) were found to be the least predictive. In Figure 2, ROC curves for anthropometric variables and indicators are presented. All variables were significantly differentiating and showed a similar course, although BMI (AUC=0.67) and WHtR (AUC=0.67) and waist circumference (AUC=0.67) proved to be the strongest differentiators. Figure 3 presents the results for the risk index, with overall (AUC=0.68) proving to be the most predictive indicator.

Table 6. The average values of the risk of metabolic syndrome in terms of anthropometric, biomedical and overall risk index ($\bar{X}$±SD) and incidence [%] of cardiovascular disease in different age groups

Age group	ARI $\bar{X}$±SD	BRI $\bar{X}$±SD	ORI $\bar{X}$±SD	Frequency of cardiovascular diseases [%]
30–39.9	3.15±1.51	0.85±0.85	4.00±2.04	4.13
40–49.9	3.50±1.46	1.01±0.80	4.52±1.90	12.35
50–69.9	3.95±1.53	1.24±0.82	5.14±1.89	15.00

Table 7. AUC analysis results with the confidence interval as the outcome and the level of significance of the result*

Variable	AUC	St. error	95% CI	*p*
Systolic BP	**0.779**	**0.027**	**0.726–0.832**	**0.0001**
Diastolic BP	**0.785**	**0.027**	**0.732–0.838**	**0.0001**
TG/HDL	0.570	0.035	0.501–0.640	0.059 (NS**)
TG	0.569	0.030	0.502–0.636	0.062 (NS)
HDL	0.548	0.038	0.474–0.622	0.19 (NS)
Glucose level	**0.588**	**0.039**	**0.510–0.665**	**0.03**
BMI	**0.668**	**0.033**	**0.603–732**	0.0001
WHR	**0.631**	**0.034**	**0.564–0.699**	**0.0001**
WHtR	**0.671**	**0.032**	**0.607–0.734**	**0.0001**
WC	**0.666**	**0.033**	**0.602–0.730**	**0.0001**
FAT%	**0.655**	**0.032**	**0.592–0.718**	**0.0001**
ARI	**0.661**	**0.032**	**0.598–0.725**	**0.0001**
BRI	**0.637**	**0.035**	**0.569–0.705**	**0.0002**
ORI	**0.681**	**0.031**	**0.620–0.743**	**0.0001**

* Statistically significant values are in bold
** Not significant

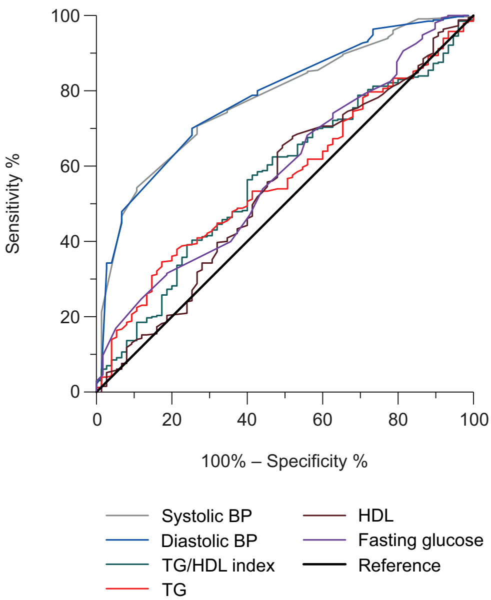

Fig. 1. ROC curves for the assessment of the risk of metabolic syndrome based on biochemical indicators and blood pressure

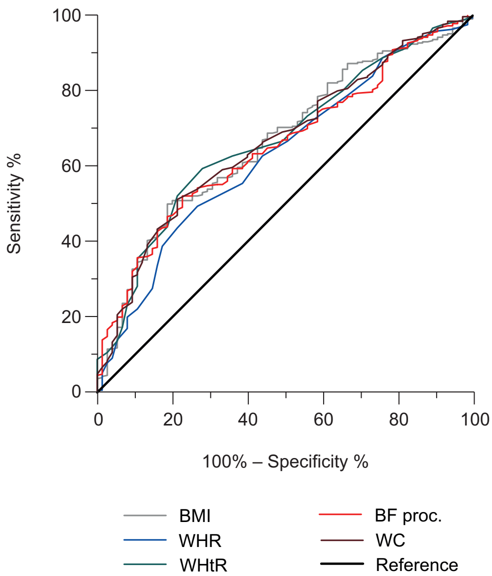

Fig. 2. ROC curves for the assessment of the risk of metabolic syndrome based on anthropometric variables

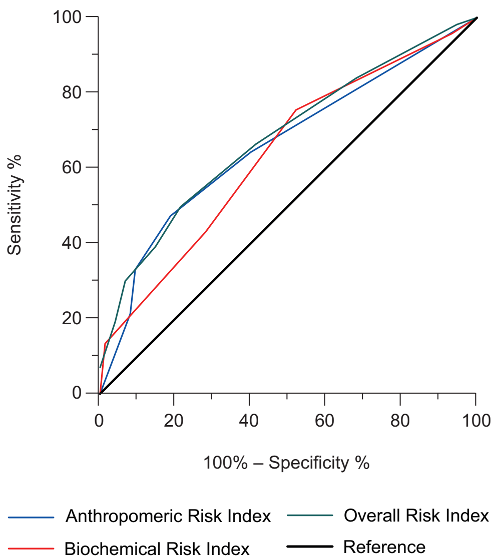

Fig. 3. ROC curves for the evaluation of metabolic syndrome, based on the different risk index's

Based on the classification of the crossing of the threshold values for individual variables and indicators, it was estimated that the respondents should be given special medical care associated with PMS by various criteria (WHO, EGIR, NCEP and IDFAccording to categories WHO, IDF, EGIR 158 men were classified as PMS, and according to the NCEP 157 of them. Then, using the chi-square relationship were calculated stochastic relationship between TMS and PMS, as well as between TMS and ARI, BRI, and ORI. Detailed data are presented in Table 8. All of the four analyzed criteria of the metabolic syndrome were significantly statistically consistent with TMS, even though the category of PMS includes more, i.e. 59–60 men (depending on criterion). All of the analyzed indicators were significantly differentiating patients and healthy men, and the highest values showed an overall risk index (chi square = 80.43, df = 1, $p<0.001$).

Discussion

This work has shown that the risk indices can be good predictors of metabolic syndrome in men working in Krakow. Among the analyzed indices is the best predictor of ORI, as the most important factor takes into account the increasing risk of metabolic syndrome, which is elevated blood pressure. Interestingly, the category of increased blood pressure by the NCEP and IDF standards, but below the standards of WHO and EGIR, included a total of less than two percent of the respondents.

Results from a representative sample of adult Polish men aged 25–85 from the province of Lower Silesia in Poland show that Krakow men's have lower values of body mass (85.9 kg vs. 80.33 kg) and waist circumference (98.5 cm vs. 92.42 cm), but higher values of blood pressure (138.8/86.3 vs. 140.98/91.07 mm Hg) (Bolanowski et al. 2010). Average adult

Table 8. The results of the relationship between TMS and PMS and risk indices (calculated chi-square test)

Dependent variable	chi-square	d.f.	*p*
PMS (WHO recommendations)	47.52	1	0.001
PMS (EGIR recommendations)	49.67	1	0.001
PMS (NCEP recommendations)	54.89	1	0.001
PMS (IDF recommendations)	43.56	1	0.001
ARI	50.00	1	0.001
BRI	67.35	1	0.001
ORI	80.43	1	0.001

height in both populations is similar (173.0 vs.173.53 cm).

Other studies using ROC analysis indicated previously a diverse diagnostic value of anthropometric indicators. Taylor et al. (1998) analysed adult women in Canada and found that only waist circumference correlated with BMI, and anthropometric indices were better predictors than waist circumference alone. Similar results were obtained in a large cross-sectional study of Germans by Schneider et al. (2007), where in both sexes BMI and waist circumference proved to be better estimators than WHR. Li and McDermott (2010), based on research of Australian aboriginal populations, show that for this population WHR is more important in the prediction of metabolic syndrome, and the worst results are obtained for BMI. The results were similar to those of Lee et al. (2008) obtained for a population of 88,514 adults surveyed in Europe, six countries in Asia and the Caribbean. BMI estimates the size of body fat, although it is assumed that a better way to assess fatness is WHR or waist circumference itself (Paniagua et al. 2008). Cut-off point of BMI for adults according to WHO standards, in the opinion of many authors, underestimated overweight and obesity, and therefore indicate the need for other predictors to take into account the body fat percentage and fat distribution (Lee et al. 2008).

Rostambeigi et al. (2010) and Gozashti et al. (2014) who studied the population of Iran and Australia confirmed the significant correlations between waist circumference and the other variables that define the existence of metabolic syndrome. Similar results were obtained for the Thai population (Worachartcheewan et al. 2012), or the inhabitants of Mexico (Lorenzo et al. 2007).

Measurements of the same weight, height, waist circumference and hip circumference are standard procedure resulting from the analyzed standards defining the metabolic syndrome. Our research shows that it is not only the use of these measurements that is important in this prediction, but also the estimation of the percentage of fat in the body. Similar findings were reported by Bisschop et al. (2013) for 40–80 aged male population in the Netherlands. In addition, it is important to take into account the standard for many different indicators simultaneously. Similar results were also obtained by Quan et al. (2013) for a population of Chinese living in large cities, when looking for the best estimators of type 2 diabetes and Lorenzo et al. (2007) for the population of Mexico (city) and San Antonio, Texas. Moreover, the Salazar et al. study (2012) showed that of biochemical parameters valid for predicting the metabolic syndrome it is necessary to take account of the new index: TG/HDL. Our results showed that in a global perspective on the problem of predicting the risk of metabolic syndrome assessment based on the ARI and BRI indicators at the same time gives the best results.

Authors' Contributions

MCh is the initiator and head of research, is the originator of work, co-author of the primary work and its final version.

JB is the initiator the work, the contractor of the research project, as well as statistical analysis and interpreter of the results of calculations, co-author of the primary work and its final version.

Conflict of interest

The authors declare no conflict of interest.

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References

Alberti KG, Zimmet PZ. 1998. Definition, diagnosis and classification of diabetes mellitus and its complications. Part 1: diagnosis and classification of diabetes mellitus provisional report of a WHO consultation. Diabet Med 15: 539–553.

Balkau B, Charles MA. 1999. Comment on the provisional report from the WHO consultation: European Group for the Study of Insulin Resistance (EGIR). Diabet Med 16: 442–443.

Bauduceau B, Vachey E, Mayaudon H, Burnat P, Dupuy O, Garcia C, Ceppa F, Bordier L. 2007. Should we have more definitions of metabolic syndrome or simply take waist measurement? Diabetes Metab 33: 333–339.

Bisschop ChNS, Peters PHM, Monninkhoff EM, van der Schouw YT, May AM. 2013. Associations of visceral fat, physical activity and muscle strength with the metabolic syndrome. Maturitas 76: 139–145.

Bolanowski J, Bronowicz J, Bolanowska B, Szklarska A, Lipowicz A, Skalik R. 2010. Impact of education and place of residence on the risk of metabolic syndrome in Polish men and women. Int J Cardiol 145: 542–544.

Gozashti MH, Najmeasadat F, Mohadeseh S, Najafipour H. 2014. Determination of most suitable cut off point of waist circumference for diagnosis of metabolic syndrome in Kerman. Diabetes Metab Syndr: *Clin Res Rev* 8: 8–12.

Huang Z, Willett WC, Manson JE, Rosner B, Stampfer MJ, Speizer FE, Colditz GA. 1998. Body weight, weight change, and risk for hypertension in women. Ann Intern Med 128: 81–88.

Lee CMY, Huxley RR, Wildman RP, Woodward M. 2008. Indices of abdominal obesity are better discriminators of cardiovascular risk factors than BMI: a meta-analysis. J Clin Epidemiol 61: 646–653.

Li M, McDermott RA. 2010. Using anthropometric indices to predict cardio-metabolic risk factors in Australian indigenous populations. Diabetes Research and Clinical Practice 87: 401–406.

Lorenzo C, Serrano-Ríos M, Martínez-Larrad MT, Gonzalez-Villalpando C, Williams K, Gabriel R, Stern MP, Haffner SM. 2007. Which Obesity Index Best Explains Prevalence Differences in Type 2 Diabetes Mellitus. Obesity. 15: 1294–1301.

Paniagua L, Lohsoonthorn V, Lertmaharit S, Jiamjarasrangsi W, Williams MA. 2008. Comparison of waist circumference, body mass index, percent body fat and other measure of adiposity in identifying cardiovascular disease risks among Thai adults. Obes Res Clin Pract 2: 215–223.

Quan MIS, Peng Y, Nan H, Hong LJ, Rong CX, Bo C, Xia YL, Hua ZW. 2013. BMI, WC, WHtR, VFI and BFI: Which Indictor is the Most Efficient Screening Index on Type 2 Diabetes in Chinese Community Population. Biomed Environ Sci, 26: 485–491.

Rostambeigi N, Shaw JE, Atkins RC, Ghanbarian A, Cameron AJ, Forbes A, Momenan A, Hadaegh F, Mirmiran P, Zimmet PZ, Azizi F, Tonkin AM. 2010. Waist circumference has heterogeneous impact on development of diabetes in different populations: longitudinal comparative study between Australia and Iran. Diabetes Res Clin Pract 88: 117–124.

Salazar MR, Carbajal HA, Espeche WG, Leiva Sisnieguez CE, Balbín E, Dulbecco CA, Aizpurúa M, Marillet AG, Reaven GM.

2012. Relation among the plasma triglyceride/high-density lipoprotein cholesterol concentration ratio, insulin resistance, and associated cardio-metabolic risk factors in men and women. Am J Cardiol 109: 1749–1753.

Schneider HJ, Glaesmer H, Klotsche J, Böhler S, Lehnert H, Zeiher AM, März W, Stalla GK, Wittchen HU, DETECT Study Group. 2007. Accuracy of anthropometric indicators of obesity to predict cardiovascular risk. J Clin Endocrinol Metab 92: 589–594.

Tatoń J, Czech A, Bernas M. 2006. Otyłość–Zespół metaboliczny, Warszawa: Wyd. Lekarskie PZWL.

Taylor RW, Keil D, Gold EJ, Williams SM, Goulding A. 1998. Body mass index, waist girth, and waist-to-hip ratio as indexes of total and regional adiposity in women: evaluation using receiver operating characteristic curves. Am J Clin Nutr 67: 44–49.

Third Report of the National Cholesterol Education Program (NCEP) expert panel on detection, evaluation and treatment of high blood cholesterol in adults (Adult Treatment Panel III) final report. Circulation 2002, 106, 3143–3421.

Worachartcheewan A, Dansethakul P, Nantasenamat C, Pidetcha P, Prachayasittikul V. 2012. Determining the optimal cut-off points for waist circumference and body mass index for identification of metabolic abnormalities and metabolic syndrome in urban Thai population. Diabetes Res Clin Pract 98: e16–e21.

Zimmet P, Alberti KG, Serrano Rios M. 2005a. A new International Diabetes Federation (IDF) worldwide definition of the metabolic syndrome: the rationale and the results. Rev Esp Cardiol 58: 1371–1376.

Zimmet P, Magliano D, Matsuzawa Y, Alberti G, Shaw J. 2005b. The metabolic syndrome: a global public health problem and a new definition. J Athero Thromb 12: 295–300.