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How well do anthropometric indices correlate with cardiovascular risk factors? A cross-sectional study in Croatia

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Data Interpretation
E Manuscript Preparation
F Literature Search
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Summary

Background: Usefulness of anthropometric indices (AI) as predictors of CV risk is unclear and remains controversial.

Material/Methods: To evaluate the correlation between AI and CV risk factors in the Croatian adult population and to observe possible differences between coastal and inland regions and urban and rural settlements. CRISIC-fm (ISRCTN31857696) is a prospective, randomized cohort study conducted in GP (general practitioner) practices in Croatia. Between May and July 2008, 59 GPs each recruited 55 participants aged ≥40 years, who visited a practice for any reason. Height, weight, waist and hip circumference and blood pressure were measured. Blood samples were analyzed in accredited laboratories.

Results: Out of 2467 participants (61.9% women, 38.1% men), 36.3% were obese, with fewer in coastal than inland areas. More obese people were in rural areas. Logistic regression showed BMI was the most important predictor of hypertension, diabetes and dyslipidemia in both regions (except for diabetes in the coastal area), and for urban and rural settlements (except for diabetes in rural areas). WtHR was a significant predictor for hypertension and dyslipidemia in the coastal (but only for hypertension in the inland area), and in urban settlements (in rural only for hypertension). None of the AI showed significant correlation with total CV risk, but WC and BMI did with stroke risk. Receiver operating curve (ROC) analyses showed that WtHR was a better predictor than all other AI for hypertension and dyslipidemia.

Conclusions: Results encourage the use of BMI and WtHR as important tools in predicting CV risk in GP's practice.

key words: **anthropometric indices • obesity • cardiovascular risk**

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Background

Correlation between obesity and CV risk was the subject of scientific debate in the last decade, since an obesity pandemic has been perceived in the world, especially in developed countries. There are 350 million obese people (BMI ≥30 kg/m²) and more than a billion are overweight (BMI ≥25 kg/m²) [1]. According to data from the Croatian Health Survey from 2003, the prevalence of obesity was 22.3%, and overweight 61.4% [2]. Thus every fifth inhabitant is obese, and about 2/3 of men and >½ of women have body weight greater than normal [3]. The correlation between obesity and type 2 diabetes, coronary disease, osteoarthritis and some malignancies is well documented [4]. The death risk in obese people is increased 1.5–2-fold compared to their normal weight peers [5]. CV diseases are the leading cause of death in Croatia, accounting for 53.6% of total mortality [6], which is a huge public health problem. According to the mortality rate of these diseases per 100 000 inhabitants; Croatia is among the European countries with the highest CV mortality [7].

Visceral obesity is a CV risk factor causally linked to arterial hypertension, insulin resistance, accelerated atherogenesis and coronary disease [8]. Various AI are used to measure obesity: BMI (body mass index), WC (waist circumference), WHR (waist-to-hip ratio), and WtHR (waist-to-height ratio). BMI indicates general obesity and was introduced by the WHO as a statistical measure of nutritional status. WC and WHR are accepted as indicators of visceral obesity. WtHR could be the most accurate anthropometric index of visceral obesity since its value is influenced only by waist circumference [9–12]. The predictive value of individual AI for CV risk is still unclear.

CRISIC-fm (Cardiovascular Risk and Intervention Study In Croatia-family medicine) ISRCTN31857696 is a national multicentric prospective, randomized, intervention-controlled cohort study on nutritional status and CV risk, conducted in 59 GPs' practices in Croatia. The study included 2467 examinees aged ≥40.

Aims

To assess the correlation between AI of obesity and CV factor, total CV and stroke risk scores in a nationally representative sample of the Croatian adult population registered with general practitioners (GP). Hypotheses were that we would observe differences in obesity and overweight across regions of Croatia (coastal/inland) and by settlement size (urban/rural) and a higher predictive value of WtHR for CV risk factors, total CV and stroke risk compared to others (BMI, WC, WHR).

Material and Methods

Design

This is a cross-sectional part of the CRISIC-fm study, conducted from May to July 2008 in 59 GP practices in Croatia. The study population comprised 2467 participants aged ≥40.

This was a 2-stage study: 1. a representative sample of GP practices was selected randomly by 4-stage stratified sampling method [county, region (coastal, inland, urban, rural and number of insured people in the GP's care in 2007]. The principal investigators of each stratum were initially selected from a random list. If the principal investigator refused to participate, the next GP on the list was invited. The list was created according to the location closest to the principal investigator, in the same stratum. GPs enrolled the first 55 consenting patients aged ≥40 (one per day), who visited the practice during the study period for whatever reason. Exclusion criteria were communication disability (dysphasia, aphasia), severe dementia or mental illness, and disease with estimated life expectancy of less than 6 months. The study was approved by the Research Ethics Committee of the Medical School of Zagreb.

All participants gave written consent.

Questionnaires and measurements

A 140-item CRISIC-fm standardized questionnaire was developed for the purpose of the project and was validated in a pilot study. Participants were interviewed (face-to-face) by trained researchers. The measures analyzed were: height and weight (the mean of 2 measurements on standardized anthropometric scales), waist and hip circumference (by plastic coated, non-elastic tape), and seated arterial blood pressure (the mean of 2 measurements performed by mercury sphygmomanometer).

Blood samples were taken for biochemical analysis (total cholesterol, HDL and LDL, triglycerides, fasting blood glucose). Diagnostic criteria of arterial hypertension, dyslipidemia and glycemia were based on the current guidelines of professional societies (Box 1). The expected 10-year risk of fatal CV disease in primary prevention was calculated using the SCORE chart for high risk countries and for stroke according to Framingham risk score [13,14].

Box 1. Diagnostic criteria for CV risk factors. (European guidelines on CVD prevention, Fourth joint european societies task force on cardiovascular disease in clinical practice, 2007).

Blood pressure > 140/90 mm Hg
Total cholesterol > 5.0 mmol/l
LDL cholesterol > 3.0 mmol/l
HDL cholesterol <1 mmol/l M, <1.2 mmol/l W
Triglicerides >1.7 mmol/l
FBG > 7.0 mmol/l on repeated measurements

M – men; W – women; LDL – low density lipoproteines; HDL – high density lipoproteines; FBG – fasting blood glucose.

Bias

Standard error of measurement was reduced by using identical standardized measuring instruments at all locations and by repeated measurements (×2). Numerical data verification and logical control of systematic errors were performed.

Statistical analysis

Descriptive statistical methods were used to describe participants' demographic characteristics. The χ^2 test was used to measure associations between 2 categorical variables (Fisher's

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Table 1. Anthropometric indices in N=2467 Croatian adults registred with GP.

	Cut-off	Inland		Coastal	
		Urban	Rural	Urban	Rural
		N (%)	N (%)	N (%)	N (%)
WC (cm)	m >102; w >88	628 (52.8)	295 (63.5)	279 (48.8)	91 (52.3)
WHR	m ≥1, w ≥0.85	95 (26.1)	88 (40.7)	35 (28.8)	8 (18.2)
BMI (kg/m2)	normal ≤24.99	267 (22.3)	78 (16.9)	137 (23.6)	41 (23.4)
	overweight 25.00–29.99	509 (42.5)	175 (38.1)	261 (44.9)	70 (40.2)
	obese ≥30.00	421 (35.2)	208 (45.1)	183 (31.5)	64 (36.4)
WtHR	≥0.50	946 (81.8)	404 (89.6)	445 (80.1)	138 (83.5)

WC – waist circumference; WHR – waist to hip ratio; BMI – body mass index; WtHR – waist to height ratio.

Table 2. Cardiovascular risk factor distribution; all figures shown as means (95% CI).

	Inland				Coastal			
	Urban N=1243		Rural N=465		Urban N=581		Rural N=177	
Systolic BP (mm Hg)	130.9	(129.8–132.0)	133.5	(131.8–135.1)	128.7	(126.9–130.6)	136.3	(132.4–140.2)
Diastolic BP (mm Hg)	80.2	(79.6–80.8)	82.0	(81.1–82.9)	79.4	(78.3–80.5)	82.4	(80.0–84.7)
TC (mmol/l)	5.9	(5.8–6.0)	5.8	(5.6–5.9)	5.9	(5.8–6.0)	5.5	(5.3–5.7)
HDL (mmol/l)	1.6	(1.5–1.6)	1.6	(1.5–1.6)	1.5	(1.5–1.6)	1.6	(1.5–1.7)
LDL (mmol/l)	3.5	(3.4–3.6)	3.6	(3.5–3.7)	3.6	(3.4–3.6)	3.3	(3.1–3.5)
Triglycerides (mmol/l)	1.8	(1.7–1.9)	2.0	(1.8–2.1)	1.8	(1.7–1.9)	1.8	(1.6–2.0)
FBG (mmol/l)	6.0	(4.9–7.1)	7.2	(5.8–8.8)	5.7	(5.6–5.8)	5.3	(5.0–5.6)

TC – total cholesterol; HDL – high density lipoproteins; LDL – low density lipoproteins; FBG – fasting blood glucose.

exact test for 2×2 tables). Logistic regression analysis determined the odds ratio (OR) and significance of the independent contribution of each AI in predicting CV risk. Sensitivity and specificity of AI as an area under a curve (AUC) for each CV risk factor were determined by receiver operating characteristic (ROC) analysis. All statistical methods were performed using SPSS for Windows (11.5, SPSS Inc., Chicago, IL, 2002), at a 95% level of significance ($P<0.05$).

Results

We obtained data from 2467 participants (61.9% women, 38.1% men; 69.3% inland, 30.7% coastal; 26.0% rural, 74.0% urban). The response rate of GPs was 71% and response rate of participants was 78%. Considering AI, 1918 (80%) participants had an increased waist circumference, 225 (30.4%) had increased WHR, 1015 (42.1%) were overweight, 875 (36.3%) were obese, and 1933 (83%) had increased WtHR according to pre-ordained criteria.

In comparing coastal/inland and urban/rural, there was a difference in BMI across regions and by the settlement size (Table 1). Chi-square test showed fewer obese people found in the coastal than in the inland areas (P=0.032). In rural areas there were more obese people ($P<0.001$), and more individuals with increased WHR (P=0.004) and increased WtHR ($P<0.001$) than in urban areas.

Systolic blood pressure ≥140mm Hg occurred more often in urban areas ($P<0.001$), and diastolic blood pressure >90 mm Hg occurred more often in inland ($P<0.041$) areas. There was no difference in dyslipidemia, while hyperglycemia was found more often in the inland population ($P<0.001$) (Table 2). Total CV risk according to SCORE did not differ across the regions according to urbanization, whereas the Framingham risk score was higher in inland than in coastal areas ($P<0.001$), and was higher in urban areas than in rural settlements ($P<0.001$).

For all logistic regressions we made adjustments for age, sex, physical activity and smoking. Among the AIs, calculated BMI >30 kg/m^2 proved to be the best predictor for hypertension, diabetes and dyslipidemia (Table 3) and was a significant predictor for all CV risks in both regions, except for diabetes in the coastal area. WtHR had a significant predictive value for 2 CV risks, hypertension and dyslipidemia

Table 3. Logistic regression analysis of anthropometric indices in CV risk prediction: OR and 95% CI (normal is taken as 1).

		Hypertension		Diabetes		Dyslipidemia		SCORE		Framingham	
		OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
WC (cm)	m >102; w >88	2.341	1.823–3.006***	2.096	1.461–3.007***	1.457	1.145–1.854**	NS	––	1.901	1.335–2.669***
WHR	m ≥1w ≥0.85	2.138	1.335–3.423**	1.979	1.349–2.904***	NS	––	NS	––	NS	––
BMI (kg/m^2)	Overweight	1.6661	1.278–2.156***	1.457	(1.014–2.093)*	1.375	1.069–1.768*	NS	––	NS	––
	Obese	3.308	2.509–4.360***	2.213	(1.546–3.168)***	1.704	1.318–2.202***	NS	––	1.591	1.002–2.526*
WtHR	≥0.50	2.508	1.901–3.310***	1.678	(1.114–2.529)*	1.577	1.203–2.066**	NS	––	NS	––

* $P<0.05$; ** $P<0.01$; *** $P<0.001$. NS – non statistically significant; WC – waist circumference; WHR – waist to hip ratio; BMI – body mass index; WtHR – waist to height ratio; m – men; w – women.

(Table 3), and was a significant predictor for all 3 CV risks in the coastal area, but only for hypertension in the inland area. Considering the settlement size, WtHR proved to be a good predictor for all 3 CV risks in urban areas, while in rural areas it was only significant for hypertension. None of the anthropometric indices showed any statistically significant independent contribution to the total CV risk by SCORE, but BMI and WC did for stroke risk according to Framingham (Table 3).

ROC analyses indicated WtHR is a better predictor of hypertension and dyslipidemia than other indices. However, for total CV risk according to SCORE and stroke risk according to Framingham, WHR was the best predictor (Table 4).

Discussion

We found that the prevalence of overweight and obesity differs across the regions and the settlements of Croatia. Our total sample included 36% obese people, compatible with data about populations registered with GPs in most European countries [15]. The greater prevalence of obesity in inland area may be explained by different patterns of diet in coastal and inland parts of Croatia. The so-called "Mediterranean dietary pattern" (fish, vegetables, olive oil) is more common in the coast areas.

BMI is an index of general obesity [16], which does not take into consideration the distribution of subcutaneous and visceral adipose tissue in the body. It is not sufficiently specific or sensitive in elderly people and does not discriminate between people with weight gain at the expense of their muscle mass compared to those with increased weight due to adipose tissue. Numerous studies have shown the greater importance of visceral obesity than general obesity because visceral obesity is strongly associated with CV risk [8,17]. Exclusive reliance on BMI in assessing obesity ignores the distribution and accumulation of abdominal fat, therefore the CV risk can easily be overlooked. X-ray densitometry, CT and MR are used for accurate measurement of abdominal adipose tissue accumulation, but they are expensive and unavailable in primary care. Measuring subcutaneous fat using skinfold callipers shows too much variability in individual measurements and therefore it is not a reliable method. However, the measurement of individual body volumes is reliable, cheap and feasible.

One disadvantage of WC is that it does not take into account individual differences in body height. On the other hand, WHR can remain apparently within the normal range in case of proportional reduction in waist and hips. With constant body height, WtHR is affected only by waist circumference increase. According to NCEP-ATP III [18] criteria for increased waist circumference, 80% of subjects in our sample were centrally obese, but only 30.4% had increased WHR and 83% had increased WtHR. This prevalence is greater than in most European countries [15], but it can be partly explained by the fact that GPs are more often visited by sick people. This is an important message for GPs who mainly care for adult patients, since CV diseases are the leading cause of death in Croatia. According to 2008 data from the Croatian Institute for Public Health, 4 085 458 out of 4 437 460 inhabitants of Croatia (92.1%) have been registered with a GP [19].

According to logistic regression analysis of our data, BMI >30 kg/m^2 was the best predictor for hypertension, diabetes and dyslipidemia, and among visceral obesity AI, WtHR ⩾0.5 was the best for hypertension and dyslipidemia. BMI was not predictive of diabetes in the coastal region, while WtHR was a predictor for all 3 CV risk factors in coastal and urban areas, and only for hypertension in inland and rural areas. Although some AI showed the correlation with individual CV risk factors, none of them was associated with overall 10-year risk of fatal CV events according to SCORE. However, the correlation showed in BMI >30 kg/m^2 and WC with 5-year stroke risk according to Framingham.

According to ROC analyses, WtHR had the greatest predictive value for 2 CV risk factors (hypertension, dyslipidemia) and WHR for total CV risk by SCORE and stroke risk according to Framingham. Estimated 10-year risk of fatal CVD

Table 4. ROC curve analysis for each AI according to CV risks.

		AUC	95% CI	*P*	Best cut-off	Sens. (%)	Spec. (%)
Hypertension	WC	0.676	0.652–0.699	<0.001	91.50	70%	56%
	WHR	0.640	0.616–0.664	<0.001	0.88	60%	60%
	BMI	0.663	0.639–0.686	<0.001	27.7	62%	62%
	WtHR	0.694	0.671–0.717	<0.001	0.55	66%	64%
Diabetes	WC	0.679	0.652–0.706	<0.001	99.50	61%	65%
	WHR	0.673	0.646–0.699	<0.001	0.91	63%	64%
	BMI	0.611	0583–0.639	<0.001	28.70	60%	56%
	WtHR	0.674	0.647–0.701	<0.001	0.58	63%	64%
Dyslipidemia	WC	0.577	0.555–0.600	<0.001	94.50	60%	51%
	WHR	0.563	0.541–0.586	<0.001	0.90	60%	48%
	BMI	0.584	0.561–0.607	<0.001	28.00	61%	53%
	WtHR	0.596	0.573–0.618	<0.001	0.56	60%	55%
SCORE	WC	0.620	0.560–0.681	<0.001	84.50	69%	50%
	WHR	0.683	0.620–0.745	<0.001	0.88	54%	73%
	BMI	0.509	0.449–0.570	0.778	24.90	58%	46%
	WtHR	0.574	0.514–0.634	0.026	0.50	63%	53%
Framingham	WC	0.635	0.602–0.667	<0.001	95.50	69%	54%
	WHR	0.651	0.619–0.683	<0.001	0.920	61%	62%
	BMI	0.554	0.521–0.587	0.002	28.00	60%	49%
	WtHR	0.623	0.590–0.655	<0.001	0.570	63%	58%

WC – waist circumference; WHR – waist to hip ratio; BMI – body mass index; WtHR – waist to height ratio; Sens. – sensititity; Spec. – specificity.

using SCORE is calculated only in primary prevention, for apparently "healthy" asymptomatic persons with no established CV disease, but with CV risk factor burden. Such patients made up only 1/3 of the total sample. Total 5-year Framingham stroke risk is calculated not only for primary prevention sample, but also in secondary prevention in patients with established CV disease. The group of secondary prevention participants was 3 times more numerous in the study, which can explain attaining statistical significance more easily. In addition, the cut-offs are different – 5% for SCORE, and 10% for Framingham.

The results of investigating the correlation between individual AI with CV risk factors differ in some countries [20–23]. They are conducted in specific ethnic groups with anthropometric features hardly comparable to the general European population. A few studies in this area were conducted in Europe, showing different and controversial results. The German cross-sectional DETECTS study demonstrated somewhat better prediction of WtHR and WC for CV risk compared to BMI and WHR [24]. In Turkey, WC in men and BMI in women proved to be predictive of arterial hypertension [25], while the Greek ATTICA study showed the highest correlation of WC with hypertension incidence compared to BMI and WHR [26]. Even the meta-analysis of de Koning et al. showed a significant correlation between WC, WHR and CV risk: for each 1 cm increase in WC, the risk of future CV event is increased by 2%, and for each 0,0001 increase in WHR by 5% [27]. Meta-analysis of 25 prospective studies done by Lee [12] found greater significance of WtHR compared to BMI in discrimination of CV risk. The strongest correlation of WtHR was found by Gelber et al. [28].

In the context of the anthropometric evaluation of the population in care, the GP should use, in addition to BMI as an AI of general obesity, one of the indices of central obesity. Among them, in our study WtHR turned out to be the best predictor for hypertension and dyslipidemia. Combination of BMI and WtHR estimation could become a simple, inexpensive and applicable instrument for CV risk factors screening in the GP's daily work.

Limitations

There are 2 main limitations to this study. First, the sample of subjects was patients registered with a GP, which does not entirely correspond to the general population sample (those without health insurance or who do not visit a GP for other reasons could not be included). Second, the usual limitation of every cross-sectional study is the existence of only a possible correlation between AI and CV risk factors, since the causal connection cannot be directly determined by such a study design.

Conclusions

The prevalence of general and central obesity is high in the population registered with a GP in Croatia. By combined use of inexpensive and simple anthropometric indices (BMI for general and WtHR for abdominal obesity) GPs could better identify individuals at increased risk for CV events. Well-timed lifestyle and pharmacological intervention when indicated could prevent new and recurrent CV events in the population under the care of GPs.

Declaration

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