Cent. Eur. J. Med. • 6(4) • 2011 • 411-417
DOI: 10.2478/s11536-011-0045-x

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Central European Journal of **Medicine**

Association between anthropometric indexes and cardiovascular risk factors

Research Article

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Received 28 February 2011; Accepted 27 April 2011

Abstract: The aim of this study was to assess the associations of the body mass index (BMI), waist circumference (WC), and waist-to-height ratio (WHtR) with ischemic heart disease (IHD) and risk factors of IHD in the Lithuanian population aged 25 to 70 years. The cross-sectional health survey was carried out in Kaunas, which is the second largest city in Lithuania, and in five regions randomly selected from the northern, southern, eastern, western and central parts of Lithuania. Data from 2048 subjects (936 men and 1112 women) were analyzed. In both sexes, the odds ratios for reduced high density lipoprotein cholesterol, elevated triglycerides, high fasting blood glucose, and hypertension rose with an increasing quartile of BMI, WC, and WHtR. The likelihood of having IHD was statistically significantly higher in the fourth quartile of these anthropometric measures when compared to the first one. Comparison of the logistic regression models revealed that the models with WHtR best fit the prediction of IHD risk. Compared with BMI and WC, WHtR showed a stronger association with IHD and its risk factors in the Lithuanian adult population.

Keywords: *Body mass index • Waist circumference • Waist-to-height ratio • Ischemic heart disease • Risk factors*

1. Introduction

Obesity is one of the most important public health problems in both developed and developing countries [1]. The prevalence of obesity has significantly increased among the world populations during the past 30 years [2,3]. Lithuania is no exception. According to the data from Lithuanian Health Behaviour Monitoring, the prevalence of obesity has risen steadily, especially in men (from 11% in 1994 to 17% in 2008), and every fifth Lithuanian woman is obese [4].

Obesity is a major risk factor for hypertension and dyslipidemia, which are, in turn, risk factors for the development of ischemic heart disease (IHD) [5-7]. The mortality rate from IHD in Lithuania is considerably higher than in the most European countries [8]. Preventive actions aimed at the reduction of IHD risk factors including obesity are the most effective way to decrease the prevalence of IHD and improve the health status of populations [9].

In recent years, discussion has increased about which measure of overweight and obesity is the best indicator to identify those individuals who are at high cardiovascular risk [7,10-12]. The most popular measures are height and weight, expressed preferably as the body mass index (BMI). This measure is used by the World Health Organization (WHO) to define severity of overweight and obesity across populations. Epidemiologic studies have revealed that accumulation of abdominal fat is also an important predictor of risk for cardiovascular disease [13,14]. The measurement of the waist circumference (WC) is used mostly for defining central obesity, but this measurement has been criticized for not taking into account differences in body height [15]. Recent studies have found that waist-to-height ratio (WHtR) may be used as marker of body fat centralization, which could be a efficient predictor of cardiovascular risk [10-15]. Some investigators have shown that the strength of

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the association between anthropometric indexes and cardiovascular risk is population-dependent [16].

The aim of this study was to assess the association of the body mass index (BMI), waist circumference (WC), and waist-to-height ratio (WHtR) with ischemic heart disease (IHD) and risk factors of IHD in the Lithuanian population aged 25 to 70 years.

2. Material and Methods

2.1. Study population

The cross-sectional health survey was carried out in 2006-2008 in Kaunas, which is the second largest city in Lithuania, and in five regions randomly selected from the northern, southern, eastern, western and central parts of Lithuania. The random samples of inhabitants aged 25 to 70 years and stratified by place of residence were drawn from the Population Register. The eligible sample included 3442 individuals. Of these, 2083 (60.5%) underwent a health examination. Individuals (N=35) with incomplete data for anthropometric measures or laboratory tests were excluded from analysis. This article presents the findings for 2048 subjects (936 men and 1112 women). The Lithuanian Bioethics Committee approved the study.

2.2. Anthropometric, clinical and biochemical measurements

The height, determined without the subject wearing shoes, was measured to the nearest centimetre with a portable stadiometer. The body weight, determined with the subject wearing light indoor clothing but no shoes, was measured to the nearest 0.1 kg with standardized medical scales. The BMI was calculated as weight divided by height squared (kg/m^2). WC was measured by standard meter at a level midway between the lower rib margin and iliac crest to the nearest 0.5 cm. WHtR was calculated as WC divided by height.

Blood pressure (BP) was measured with a standard mercury sphygmomanometer on the right arm of the participant, who was seated for 5 minutes before the measurement. Two BP measurements were taken, and the average was calculated and used in the analysis. Participants were classified as hypertensive if their systolic BP was ≥ 140 mm Hg and/or their diastolic BP was ≥ 90 mm Hg or if they had received antihypertensive drug treatment for the previous 2 weeks.

Blood samples for lipid measurements were taken in the morning after fasting at least 12 hours. Total serum cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), and triglyceride (TG) levels were determined by automatic analyser by conventional enzymatic methods in a certified laboratory. Dyslipidemia was defined by the National Cholesterol Education Program Adult Treatment Panel III criteria [17]. High TC level was defined as total serum cholesterol ≥ 6.2 mmol/L; high LDL-C as LDL-C level ≥ 4.1 mmol/L; elevated TG as TG level ≥ 1.7 mmol/L. Reduced HDL-C level for men was defined as HDL-C < 1.0 mmol/L and for women as < 1.3 mmol/L. The glucose level in capillary blood was determined with a glucometer. Hyperglycaemia was defined as a fasting blood glucose (FBG) level ≥ 6.1 mmol/L.

Information on smoking was determined via a standard questionnaire; a person who smoked at least one cigarette per day was considered a regular smoker.

2.3. Criteria for ischemic heart disease

IHD was determined according to the medical history, the Rose questionnaire [18], and electrocardiogram (ECG) data coded by the Minnesota codes [19]. The diagnosis of IHD was based on a documented history of myocardial infarction or angina pectoris as defined by the Rose questionnaire or Minnesota codes I_{1-3}, IV_{1-3}, V_{1-3} VI_{1-2}, VII_{1}, and $VIII_{3}$.

2.4. Statistical methods

The data were analysed with SPSS version 19.0 for Windows. Analyses were performed separately for men and women. The data were weighted to match the age distribution of the Lithuanian population aged 25 to 70 years in 2008. Continuous variables were presented as mean values and standard deviation, and categorical variables were expressed as proportion. Associations between categorical variables were tested by the χ^2 test, whereas differences between distributions of continuous variables were tested via the Student t test after logarithmic transformation of the variables that were not distributed normally. Pearson correlation coefficients between anthropometric indexes and IHD risk factors were calculated. Quartiles of BMI, WC and WHtR were obtained separately for men and women. Multiple logistic regression analysis was used to calculate odds ratios of IHD and risk factors by the quartiles of anthropometric indexes. Independent variables in the logistic regression models were age as a continuous variable and smoking habit as a categorical variable. Akaike's Information Criterion (AIC) and Bayesian information criterion (BIC) were used to compare the logistic regression models.

Table 1. Mean values and standard deviations (SD) of age, anthropometric indexes and ischemic heart disease risk factors of study population.

Characteristics	Men N = 936	Women N=1112	p value
Age (years)	54.2 (10.8)	52.4 (11.9)	<0.001
BMI (kg/m^2)	27.7 (4.93)	28.3 (6.38)	0.017
WC(cm)	93.8 (12.8)	86.3 (14.3)	<0.001
WHtR	0.53 (0.07)	0.53 (0.09)	0.6
Systolic BP (mmHg)	143.6 (21.4)	136.8 (23.9)	<0.001
Diastolic BP (mmHg)	92.6 (12.3)	86.1 (11.6)	<0.001
TC (mmol/L)	5.43 (1.08)	5.49 (1.18)	0.2
TG (mmol/L)	1.53 (0.77)	1.43 (0.60)	0.001
LDL-C (mmol/L)	3.47 (1.00)	3.38 (1.07)	0.036
HDL-C (mmol/L)	1.32 (0.42)	1.47 (0.36)	<0.001
FBG (mmol/L)	5.29 (1.10)	5.27 (1.20)	0.7

Anthropometric indexes and risk factors adjusted by age.
BMI - body mass index; WC - waist circumference; WHtR - waist-to-height ratio; BP - blood pressure; TC - total cholesterol; TG - triglycerides level; LDL-C - low density lipoprotein cholesterol; HDL- C - high density lipoprotein cholesterol level; FBG - fasting blood glucose level.

Table 2. Prevalence of ischemic heart disease (IHD) and risk factors (%) in study population

Characteristics	Men N = 936	Women N=1112	p value
IHD	11.06	12.37	0.36
Hypertension	65.89	51.71	<0.001
High FBG	14.70	14.60	0.97
High TC	20.87	23.71	0.12
High LDL cholesterol	25.74	21.52	0.024
Reduced HDL cholesterol	19.20	33.20	<0.001
Elevated TG	30.20	25.57	0.019
Smoking. %	42.25	13.13	<0.001

Data adjusted by age.
Hypertension - systolic blood pressure ≥140 and/or diastolic blood pressure ≥90 mm Hg or under treatment; High FBG - fasting blood glucose level ≥ 6.1 mmol/L; High TC - total cholesterol ≥6.2 mmol/L; High LDL-C - low density lipoprotein cholesterol ≥4.1 mmol/L; Reduced HDL- C - high density lipoprotein cholesterol level for men<1.0 mmol/L and for women <1.30 mmol/L; Elevated TG - triglycerides level ≥1.7 mmol/L.

3. Results

Table 1 summarizes the mean values of anthropometric indexes and IHD risk factors by gender. The mean BMI and WC were higher in women than in men. No gender differences were found in the mean WHtR. Mean values of systolic and diastolic BP, TG and LDL-C were higher in men than in women and the mean value of HDL-C was lower in men. IHD risk factors such as arterial hypertension, high LDL-C, reduced HDL-C, elevated TG, and smoking were more prevalent among men than among women (Table 2).

All anthropometric indexes correlated significantly with IHD risk factors in men and in women (Table 3). The correlation of the WHtR with systolic BP in men and with FBG level in women was significantly higher than the correlation of BMI with the same factors.

The cut-off points for quartiles of anthropometric indexes are shown in Table 4. The adjusted odds ratios for the presence of risk factors for IHD according to quartiles of anthropometric indexes are summarized in Table 5. In men, odds ratios rose with the increasing quartile of BMI, WC, and WHtR. The highest increase was found in odds ratios for reduced HDL-C, elevated TG, high FBG, and hypertension. The increase in odds ratios according to WHtR and WC quartiles were slightly higher than according to BMI quartiles. Comparison of the logistic regression models with AIC and BIC revealed that the models with WHtR had the lowest values for both criteria, i.e., the best fit for prediction of IHD risk factors. In women, statistically significant odds ratios for high TC and high LDL-C were defined in only the third quartile of all anthropometric indexes. The odds ratios for other IHD risk factors rose with the increasing quartile of anthropometric measures (Table 5). The odds ratios for hypertension were highest in BMI quartiles,

Table 3. Pearson's correlation coefficients between anthropometric index and ischemic heart.

	BMI	WC	WHtR
Men (n=936)			
TC	0.095	0.113	0.133
LDL-C	0.150	0.148	0.160
HDL-C	-0.315	-0.270	-0.236
TG	0.282	0.274	0.258
FBG	0.304	0.347	0.367
SBP	0.282	0.327	0.369*
DBP	0.360	0.386	0.391
Women (n=1115)			
TC	0.098	0.133	0.164
LDL-C	0.141	0.168	0.196
HDL-C	-0.229	-0.256	-0.245
TG	0.190	0.214	0.218
FBG	0.332	0.407	0.425*
SBP	0.359	0.396	0.426
DBP	0.373	0.412	0.420

Data are correlation coefficients.
All correlation coefficients are statistically significant.
** - p<0.05 compared with corresponding BMI coefficients.*
BMI - body mass index; WC - waist circumference; WHtR - waist-to-height ratio; TC - total cholesterol; LDL-C - low density lipoprotein cholesterol; HDL- C - high density lipoprotein cholesterol; TG – triglycerides; FBG - fasting blood glucose; SBP – systolic blood pressure; DBP – diastolic blood pressure.

those for elevated TG were highest in WC quartiles, and those for reduced HDL-C and high FBG were highest in WHtR quartiles.

In both men and women, the likelihood of having IHD was statistically significantly higher in the fourth quartile of all anthropometric measures when compared to the first quartile (Figure 1) Logistic regression models with WHtR had the lowest values of AIC and BIC, i.e., better predicting the prevalence of IHD than models with WC or BMI.

4. Discussion

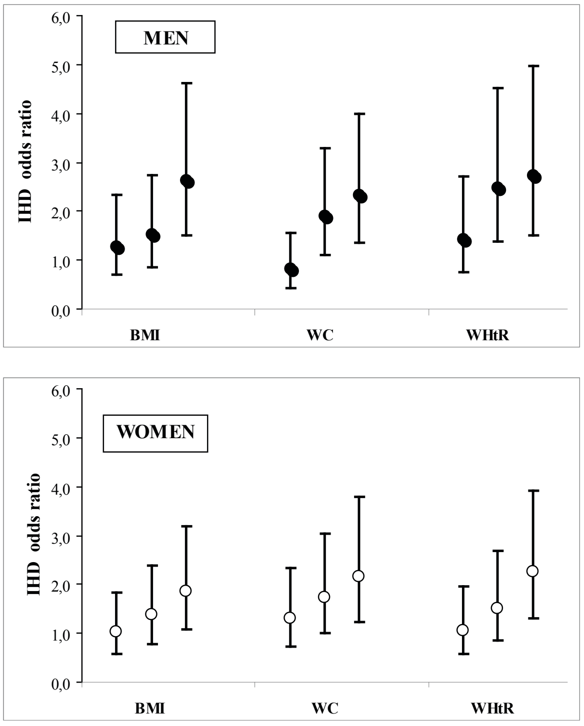
Obesity is a risk factor for diabetes mellitus, hypertension, dyslipidemia, and cardiovascular disease (CVD) [7,20-24]. Persistent obesity dysregulates metabolic processes, including action of insulin on glucose-lipid-free fatty acid metabolism, and severely affects processes controlling blood glucose levels, blood pressure, and lipids [25]. This leads to the development of the metabolic syndrome, which is comprised of a cluster of conditions including hyperglycaemia, dyslipidemia, and hypertension and is one of the main risk factors for CVD. According to Health Statistics of Lithuania, more than half of all deaths (55.4%) in 2009 were caused by cardiovascular diseases [26], and IHD accounted for almost two thirds (61.9%) of cardiovascular deaths. Therefore, it is very important to identify individuals at high risk of IHD to implement strategic measures for

Table 4. The cut-off points for quartiles of body mass index (BMI), waist circumference (WC), waist-to-height ratio (WHtR).

Variables	Men	Women
BMI. kg/m^2		
25th percentile	24.71	24.46
50th percentile	27.63	28.21
75th percentile	30.62	32.34
WC. cm		
25th percentile	86.0	77.0
50th percentile	94.2	86.0
75th percentile	102.1	97.0
WHtR		
25th percentile	0.493	0.473
50th percentile	0.541	0.533
75th percentile	0.590	0.601

BMI - body mass index; WC - waist circumference; WHtR - waist-to-height ratio.

Figure 1. Age adjusted odds ratio for ischemic heart disease (IHD) in quartiles of anthropometric indexes (BMI, WC, WHtR) in Lithuanian adult population (reference group – first quartile).



BMI - body mass index; WC - waist circumference; WHtR - waist -to-height ratio.

Table 5. Odds ratios for ischemic heart disease risk factors by body mass index (BMI), waist circumference (WC), and waist-to-height ratio (WHtR).

	High TC OR (95%CI)	High LDL-C OR (95%CI)	ReducedHDL-C OR (95%CI)	ElevatedTG OR (95%CI)	HighFBG OR (95%CI)	Hypertension OR (95%CI)
MEN						
BMI						
1st quartile	1	1	1	1	1	1
2nd quartile	2.31 (1.45-3.67)	2.59 (1.63-4.10)	2.36 (1.24-4.49)	2.11 (1.32-3.37)	2.40 (1.30-4.43)	1.44 (0.97-2.13)
3rd quartile	1.91 (1.19-3.07)	2.44 (1.53-3.89)	3.31 (1.77-6.20)	2.80 (1.76-4.46)	2.03 (1.08-3.79)	2.37 (1.56-3.60)
4th quartile	1.99 (1.24-3.22)	2.65 (1.66-4.23)	5.09 (2.74-9.45)	5.12 (3.22-8.14)	5.28 (2.94-9.47)	5.49 (3.32-9.06)
WC						
1st quartile	1	1	1	1	1	1
2nd quartile	2.07 (1.30-3.30)	2.60 (1.66-4.07)	2.88 (1.55-5.33)	1.83 (1.15-2.90)	2.59 (1.36-4.96)	1.53 (1.04-2.25)
3rd quartile	2.17 (1.37-3.44)	2.15 (1.37-3.38)	2.77 (1.49-5.15)	2.77 (1.77-4.34)	2.77 (1.47-5.22)	2.24 (1.50-3.35)
4th quartile	2.08 (1.30-3.33)	2.47 (1.57-3.89)	4.85 (2.65-8.86)	4.79 (3.05-7.51)	6.72 (3.68-12.3)	9.73 (5.46-17.3)
WHtR						
1st quartile	1	1	1	1	1	1
2nd quartile	2.24 (1.37-3.66)	1.96 (1.24-3.09)	2.56 (1.37-4.76)	2.06 (1.29-3.29)	1.50 (0.78-2.86)	1.64 (1.12-2.41)
3rd quartile	2.79 (1.72-4.53)	2.42 (1.54-3.80)	2.88 (1.53-5.40)	3.09 (1.94-4.93)	2.31 (1.25-4.26)	3.18 (2.08-4.85)
4th quartile	2.61 (1.59-4.28)	2.38 (1.50-3.77)	5.38 (2.91-9.95)	5.27 (3.30-8.43)	5.77 (3.22-10.3)	7.97 (4.65-13.6)
WOMEN						
BMI						
1st quartile	1	1	1	1	1	1
2nd quartile	1.33 (0.87-2.04)	1.35 (0.86-2.11)	1.28 (0.85-1.93)	1.19 (0.77-1.81)	1.59 (0.80-3.16)	2.43 (1.65-3.59)
3rd quartile	1.67 (1.10-2.53)	1.83 (1.18-2.83)	2.43 (1.64-3.59)	1.87 (1.24-2.80)	3.74 (1.99-7.01)	5.82 (3.87-8.75)
4th quartile	1.07 (0.70-1.65)	1.29 (0.83-4.02)	3.94 (2.65-5.86)	2.31 (1.54-3.47)	5.89 (3.17-10.9)	10.1 (6.45-15.8)
WC						
1st quartile	1	1	1	1	1	1
2nd quartile	1.46 (0.96-2.21)	1.56 (1.00-2.42)	1.51 (1.00-2.28)	1.29 (0.85-1.95)	2.51 (1.22-5.17)	1.89 (1.30-2.77)
3rd quartile	1.56 (1.04-2.35)	1.66 (1.08-2.55)	2.88 (1.94-4.29)	1.67 (1.12-2.51)	5.10 (2.58-10.1)	5.45 (3.64-8.14)
4th quartile	1.23 (0.80-1.83)	1.44 (0.93-2.25)	5.29 (3.52-7.94)	2.54 (1.70-3.82)	7.38(3.75-14.5)	8.14 (5.22-16.7)
WHtR						
1st quartile	1	1	1	1	1	1
2nd quartile	1.50 (0.98-2.31)	1.48 (0.94-2.32)	1.52 (1.00-2.30)	1.27 (0.83-1.95)	2.63 (1.29-5.38)	2.29 (1.56-3.35)
3rd quartile	1.69 (1.11-2.59)	1.81 (1.16-2.82)	3.08 (2.05-4.63)	1.87 (1.23-2.82)	3.94 (1.96-7.89)	5.20 (3.47-7.80)
4th quartile	1.39 (0.91-2.14)	1.51 (0.96-2.37)	5.31 (3.51-8.04)	2.49 (1.65-3.77)	7.65 (3.89-15.0)	9.62 (6.13-15.1)

Data adjusted by age and smoking habits.
OR – odds ratio; CI - confidence interval.
High TC - total cholesterol ≥6.2 mmol/L; High LDL-C - low density lipoprotein cholesterol ≥4.1 mmol/L; Elevated TG - triglycerides level ≥1.7 mmol/L; Reduced HDL- C - high density lipoprotein cholesterol level for men <1.0 mmol/L and for women <1.30 mmol/L; High FBG - fasting blood glucose level ≥ 6.1 mmol/L; Hypertension - systolic blood pressure ≥140 and/or diastolic blood pressure ≥90 mm Hg or under treatment.

prevention of IHD. BMI was long used as a standard measure of overweight and obesity. Recently there has been increased discussion regarding which measure of overweight and obesity is best able to demonstrate which individuals are at high cardiovascular risk [7,10-12]. In this study we compared the association of the anthropometric measures BMI, WC, WHtR with the prevalence of IHD and its risk factors in the Lithuanian population. The results of our study showed that BMI, WC, and WHtR significantly correlated with risk factors for IHD, however, the correlation of the WHtR with the systolic BP in men and with FBG in women was significantly higher than the correlation of BMI with the same factors. The logistic regression models with WHtR better predicted IHD risk than models with BMI and WC. Our data agree with the findings of a meta-analysis of relevant studies that included 88,000 individuals from diverse populations and concluded that WHtR was the best discriminator for hypertension, diabetes, and dyslipidemia in both sexes [7]. The DETECT (Diabetes Cardiovascular Risk-Evaluation: Targets and Essential Data for Commitment of Treatment) study revealed that WHtR or WC may predict cardiovascular risk better than BMI, even though the differences were small [10]. Also, the association of cardiovascular risk with WHtR has been found to be stronger than with BMI in the Korean adult population [11].

Those findings can be explained by several approaches. WHtR takes into account the distribution of body fat in the abdominal region, since central obesity has been shown to be stronger predictor of risk for cardiovascular disease than body weight [22,27,28]. Abdominal adiposity has been related to adverse lipid profile, insulin resistance, haemostatic disorders, and hypertension, which are the key factors in the pathogenesis of atherosclerosis [29].

WC is a simple measure of abdominal obesity. However, it does not take into account differences in height. It has been proven that an individual's percentage of body fat is higher in shorter people compared to taller people with an equivalent BMI [13]. Some studies have shown that WHtR is a better predictor of cardiovascular mortality and risk factors for cardiovascular disease than WC [15,21,30]. WHtR is also a simple, inexpensive anthropometric indicator, which is easily obtained in resource-poor countries and is useful for large epidemiologic surveys [7]. The WHtR has been suggested as a common measure of central obesity for use in European subjects (cut-off level of 0.5 for both sexes) [31]. The results of our study favour the use of WHtR, although further prospective studies are needed for a definite conclusion as to the best predictor of cardiovascular events in Lithuania.

Limitation. This is a cross-sectional study; therefore, these findings should be interpreted against that background. Our data show only the association with conditions that are presently risk factors, but they do not directly predict the risk of future cardiovascular events.

5. Conclusion

All our anthropometric indexes such as BMI, WC and WHtR significantly correlated with IHD risk factors in the Lithuanian adult population. However, logistic regression models with WHtR better predicted the prevalence of IHD and its risk factors than models with WC or BMI.

Acknowledgement

The study was supported by research grant from the Research Council of Lithuania for National Research Programme 'Chronic Noncommunicable Diseases' (Agreement No. LIG-02/2010).

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