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Anthropometric, metabolic and clinical factors associated with diabetes and prediabetes prevalence in women aged 65–74 living in central Poland

ABSTRACT

Background. Prevalence of type 2 diabetes mellitus is rising worldwide. Similar trend is also observed in Poland, especially in elderly population. The aim of this cross-sectional study was to assess prevalence and to identify anthropometric, metabolic and clinical factors associated with diabetes and prediabetes among women at early elderliness living in central Poland.

Methods. 364 women aged 65–74 years, were included into the study. In all patients a history of diabetes and cardiovascular disease was obtained, blood pressure and anthropometric measurements were performed, blood samples for laboratory tests (fasting plasma glucose, lipid metabolism and creatinine) were drawn, ankle/brachial index was calculated, abdominal ultrasound with abdominal aorta diameter was performed and carotid intima/media thickness was measured. Data were collected during March and April 2012 in Gniewkowo, the rural-urban municipality in central Poland.

Results. 98 women had diabetes (25 *de novo*) and 94 ones had prediabetes (81 *de novo*). Waist circumference, BMI, lipid abnormalities as well as anthropometric and metabolic indices: waist-to-height ratio (WHtR), triglycerides/HDL cholesterol ratio and visceral adiposity index (VAI) were significantly associated with abnormal glucose metabolism. Backward stepwise logistic regression analysis identified WHtR as the best single indicator of patients with diabetes, while again WHtR and VAI were the only independent indicators of any type of impaired glucose metabolism.

Conclusions. Abnormal glucose metabolism is highly prevalent among women at early elderliness, especially in those with visceral obesity and abnormal lipid metabolism. Anthropometric and metabolic indices (WHtR and VAI) were better indicators of impaired glucose metabolism compared to separate measurements of single parameters. (Clin Diabetol 2019; 8, 5: 238–247)

Key words: diabetes, prediabetes, obesity, anthropometric parameters, metabolic parameters

Introduction

Prevalence of diabetes mellitus (DM), predominantly type 2, reached an epidemic range with 425 million people suffering from DM worldwide in 2017 [1]. In Poland, according to National Health Fund data, almost 2.34 million people (6.08% of the whole population) were using antidiabetic medications in 2014 [2]. Type 2 DM is especially highly prevalent among elderly [3]. In South-Eastern Poland its prevalence in people

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aged > 65 exceeded 18% of population at that age range (the National Health Fund data, unpublished). However, known DM is only a part of the problem. The second part is a large number of people not aware of having DM, and this number reaches in Europe 37.9% of all cases of DM [1]. Moreover, the number of people having impaired fasting glucose (IFG), and/or impaired glucose tolerance (IGT) is similar to that with DM [1]. It is well known that DM can lead to several negative long-term health consequences including increased risk of cardiovascular diseases, chronic kidney disease, visual impairment, diabetic neuropathy and cancer [4]. Thus, early diagnosis of DM or prediabetes (IFG and/or IGT) is of utmost importance for the patients' prognosis.

The primary objective of this cross-sectional study was to identify the prevalence of known and undiagnosed glucose metabolism abnormalities: DM and prediabetes among women at early elderliness, living in a rural-urban community in central Poland. The secondary objective was to identify among analyzed variables the best indicators and predictors of overt DM as well as prediabetes.

Material and methods

Study participants

All women aged 65–74 years, living in Gniewkowo, the rural-urban community in central Poland, and being under care of a primary care clinics, were invited to participate in the study. We decided to choose females in such age range, due to high expected prevalence of glucose metabolism abnormalities in this population, and expected survival time long enough to develop chronic complications of diabetes — in the year 2016 life expectancy in Poland reached 20.4 years for women aged 65, and 13.5 years for women aged 74 [5]. Population of women living in this community is homogenous, and all invited females were of Caucasian ethnicity. In response to the invitation 364 women agreed to participate in the study, which accounted for about 60% of all invited ones.

Data collection

Data were collected in March and April 2012. All women were interviewed for DM and cardiovascular diseases (CVD) history and also demographic data were collected. Then weight, height, waist and hip circumference were measured and upon these data body mass index (BMI), waist/hip ratio (WHR) and waist-to-height ratio (WHtR)were calculated. Women with BMI ≥ 25.0 kg/m^2 were considered overweight and with BMI ≥ 30.0 kg/m^2 obese. Blood pressure was measured by trained nursing staff with the use of standardized sphygmomanometer validated by the appropriate authorities. Measurement on the ankles was performed with the use of a Doppler probe and the ankle/brachial index (ABI) was calculated. To assess the cardio-metabolic risk the lowest ABI score was taken into analysis. Fasting blood samples were collected for the assessment of plasma glucose concentration, serum lipid profile and creatinine level, and they were analyzed in a certified laboratory. Estimated glomerular filtration rate (eGFR) was calculated using Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI$_{cr}$) equation, currently recommended by Diabetes Poland [6, 7]:

$$GFR = 141 \times \min(Scr/\kappa, 1)^{\alpha} \times \max(Scr/\kappa, 1)^{-1.209} \times \times 0.993^{Age} \times 1.018\ [\text{if female}] \times 1.159\ [\text{if black}]$$

Scr is serum creatinine [mg/dL], κ is 0.7 for females and 0.9 for males, α is –0,329 for females and –0.411 for males, min indicates the minimum of Scr/κ or 1, and max indicates the maximum of Scr/κ or 1

In women with fasting plasma glucose ≥ 126 mg/dL measurement was repeated, while in females with fasting glycaemia within IFG range (100–129 mg/dL) oral glucose tolerance test (OGTT) was performed. DM, IFG or IGF were diagnosed in accordance with Diabetes Poland criteria from 2012 (which were identical to current ones) [7]. Metabolic syndrome (MS) was diagnosed according to the most current consensus definition [8]. Upon obtained data also two metabolic indices were calculated: Triglycerides (TG) to HDL cholesterol (TG/HDL) ratio (expressed in mg/dL) and visceral adiposity index (VAI). VAI was calculated using formula developed by Amato et al. [9] for women:

$$VAI = \left[\frac{WC}{36.58 + (1.89 \times BMI)}\right] \times \left[\frac{TG}{0.81}\right] \times \left[\frac{1.52}{HDL}\right]$$

TG and HDL cholesterol expressed in mg/dL.

Also, all patients underwent abdominal ultrasound examination with the assessment of abdominal aorta diameter, and carotid intima/media thickness (CIMT) measurement to assess the relationship between these results and status of the glucose metabolism in the study participants. Abdominal ultrasound examination was performed using a convex transducer and the diameter measurement was made on the abdominal aorta (from renal arteries to the bifurcation). Carotid intima/media thickness measurement was performed using a linear transducer. The ultrasound measurements were performed by a trained radiologists with the required certification for ultrasound examination. The highest CIMT measurement outcome was used in the analysis.

To avoid bias associated with failure to report of a 40% of the primarily invited women, 40 randomly selected women from that group were re-invited. They

reported to the clinic, where they underwent anthropometric and blood pressure measurements. Their results were not significantly different from the first group of women. They were not included in the analysis, because they did not undergo laboratory tests, ABI measurement, abdominal ultrasound and CIMT measurement.

Ethical approval

The study was approved by the Bioethics Committee at the Collegium Medicum in Bydgoszcz of the Nicolaus Copernicus University in Toruń and it was conducted in accordance with ethical standards laid down in an appropriate version of the Declaration of Helsinki and in Polish national regulations. All study participants signed informed consent form before beginning of the study procedures.

Statistical analysis

Statistical analysis of the data was performed using SigmaPlot for Windows, version 12.5 (Systat Software Inc., San Jose, CA, USA). The nominal variables are presented as numbers and percentage. The continuous data are presented as mean and standard deviation (SD) in parentheses. The normality of data distribution was checked using the Shapiro-Wilk test. Differences between groups (diabetes, prediabetes and normal glucose tolerance) were analyzed using an unpaired two-tailed Student's t-test or by a Mann-Whitney rank sum test where appropriate. The categorical data were compared using χ^2 test. We also calculated odds ratios (OR) and area under curve (AUC) in receiver operating characteristics (ROC) curve for significant associations between impaired glucose metabolism and analyzed variables. Linear correlation between continuous variables was analyzed with the use of Spearman Rank Order Correlation test. To identify predictive variables for glucose metabolism abnormalities we used backward stepwise regression analysis. We assumed a P value of < 0.05 as statistically significant.

Results

Impaired glucose metabolism (IGM = DM + prediabetes) was found in more than half of 364 included women. DM was found in 98 of them and 94 females had prediabetes. In this number there were 25 cases of newly diagnosed DM and 81 new cases of prediabetes revealed in OGTT. Overall, 55.2% of women with IGM were unaware of having abnormal glucose metabolism. MS was present in 60.7% of cases. Impaired kidney function with eGFR < 60 mL/min/1.73 m^2 was found in 37 cases (10.2% of the study participants).

We found significant differences between women with diabetes, prediabetes, IGM and normal glucose tolerance (NGT) in anthropometric parameters. BMI, prevalence of obesity, waist and hip circumference, WHR and WHtR were significantly lower in women with NGT, and they were increasing along with with the degree of glucose metabolism impairment. Women with DM compared to females with prediabetes had significantly higher BMI, WC and WHtR (Table 1).

The number of females with the history of myocardial infarction (MI) was insignificantly different between DM and NGT groups, P = 0.051 (Table 2). However, women with the history of MI had over 3-fold higher probability of having diabetes compared to the rest of study participants, odds ratio (OR) 3.26, and 95% confidence interval (CI, 1.22–8.71), P = 0.028. Hypertension was significantly less frequent among women with NGT compared to IGM and prediabetes groups. Women with NGT had also significantly lower systolic blood pressure (SBP) compared to females with DM, and significantly lower pulse pressure compared to women with DM and IGM. Diastolic blood pressure (DBP) was not significantly different between the study groups (Table 2). Although no significant differences were found between the groups with regards to vascular parameters, we revealed, which is interesting finding, significantly lower abdominal aorta diameter in 25 women with newly diagnosed DM (upon fasting plasma glucose level or in OGTT) compared to females with known DM, prediabetes and NGT: 17.0 ± 2.5 cm *vs.* 18.6 ± 2.9 cm, 18.1 ± 2.2 cm and 18.6 ± 3.4 cm respectively. P values for comparisons between new DM *vs.* known DM, prediabetes and NGT were P = 0.005, P = 0.011 and P = 0.005 respectively. Neither ABI nor CIMT was significantly different between DM, prediabetes and NGT groups (Table 2). However, we found borderline significant linear correlation between CIMT and fasting plasma glucose, R = 0.105, P = 0.046. Kidney function was significantly worse in women with prediabetes and IGM compared to NGT group. However, number of females with eGFR $\geq$ 90, 60–89 and < 60 mL/min/1.73 m^2 was not significantly different between the groups (Table 2).

All metabolic parameters and indices were significantly different between NGT and DM or IGM groups (Table 3). However, females with DM were significantly more frequently using statins compared to women with prediabetes and NGT (61.2%, 37.2% and 38,4% respectively), and after adjustment to statin use, differences between DM or IGM and NGT groups regarding total, non-HDL and LDL cholesterol became insignificant. Prevalence of MS was significantly higher in women with DM, prediabetes and IGM compared to NGT group, 90,8%, 92,6%, 91.7% and 26,2% respectively. Presence of MS was associated with 10-fold higher

Table 1. Demographic and anthropometric characteristics of the study population divided into four subgroups. The results are presented as mean and standard deviation (SD) or number and percentage. Significant differences in bold italic

Variable	Diabetes (A) n = 98	IFG/IGT (B) n = 94	IGM (C) n = 192	NGT (D) n = 172	P value			
	Mean ± SD or n (%)	Mean ± SD or n (%)	Mean ± SD or n (%)	Mean ± SD or n (%)	A *vs.* B	A *vs.* D	B *vs.* D	C *vs.* D
Age (years)	69.3 ± 3.2	69.5 ± 3.4	69.4 ± 3.3	69.0 ± 3.3	0.779	0.290	0.181	0.147
Smoking (n)	31 (31.6)	24 (25.5)	55 (28.6)	61 (35.5)	0.438	0.613	0.128	0.200
BMI [kg/m^2]	32.8 ± 5.3	31.0 ± 5.0	31.9 ± 5.2	29.2 ± 5.0	***0.022***	***< 0.001***	***0.004***	***< 0.001***
Normal weight (n)	6 (6.1)	11 (11.7)	17 (8.9)	34 (19.8)				
Overweight (n)	24 (24.5)	32 (34.0)	56 (29.2)	68 (39.5)	p_{trend} 0.084	***p_{trend} < 0.001***	p_{trend} 0.071	***p_{trend} < 0.001***
Obesity (n)	68 (69.4)	51 (54.3)	119 (62.0)	70 (40.7)				
WC [cm]	103.5 ± 11.6	100.2 ± 11.1	101.8 ± 11.4	93.7 ± 12.1	***0.046***	***< 0.001***	***< 0.001***	***< 0.001***
Hip [cm]	116.0 ± 9.9	113.7 ± 10.5	114.8 ± 10.2	109.3 ± 11.1	0.120	***< 0.001***	***0.002***	***< 0.001***
WHR	0.89 ± 0.08	0.88 ± 0.06	0.89 ± 0.07	0.86 ± 0.08	0.102	***< 0.001***	***< 0.001***	***< 0.001***
WHtR	0.66 ± 0.08	0.64 ± 0.07	0.65 ± 0.08	0.60 ± 0.08	***0.014***	***< 0.001***	***< 0.001***	***< 0.001***

IGM — impaired glucose metabolism; NGT — normal glucose tolerance; BMI — body mass index; WC — waist circumference; WHR — waist/hip ratio; WHtR — waist-to-height ratio

Table 2. Clinical and vascular parameters of the study population divided into four subgroups. The results are presented as mean and standard deviation (SD) or number and percentage. Significant differences in bold italic

Variable	Diabetes (A) n = 98	Prediabetes (B) n = 94	IGM (C) n = 192	NGT (D) n = 172	P value			
	Mean ± SD or n (%)	Mean ± SD or n (%)	Mean ± SD or n (%)	Mean ± SD or n (%)	A *vs.* B	A *vs.* D	B *vs.* D	C *vs.* D
Comorbidities								
History of MI (n)	9 (9.2)	3 (3.2)	12 (6.3)	5 (2.9)	0.157	0.051	0.806	0.208
History of stroke (n)	5 (5.1)	1 (1.1)	6 (3.1)	5 (2.9)	0.233	0.560	0.592	0.853
Hypertension (n)	84 (85.7)	82 (87.2)	166 (86.5)	131 (76.2)	0.923	0.086	***0.045***	***0.017***
Blood pressure								
SBP [mm Hg]	154.7 ± 22.6	149.1 ± 20.2	152.0 ± 21.6	148.3 ± 22.6	0.069	***0.020***	0.553	0.074
DBP [mm Hg]	84.8 ± 10.2	82.3 ± 9.9	83.6 ± 10.1	83.9 ± 10.9	0.086	0.547	0.223	0.794
Pulse pressure [mm Hg]	69.9 ± 17.9	66.8 ± 16.2	68.4 ± 17.1	64.3 ± 16.2	0.204	***0.011***	0.156	***0.015***
Vascular parameters								
ABI	0.97 ± 0.18	0.99 ± 0.15	0.98 ± 0.17	0.98 ± 0.15	0.484	0.983	0.430	0.647
CIMT [mm]	1.07 ± 0.19	1.08 ± 0.20	1.07 ± 0.19	1.06 ± 0.23	0.865	0.231	0.190	0.128
AAD [mm]	18.2 ± 2.9	18.1 ± 2.2	18.1 ± 2.6	18.6 ± 3.4	0.852	0.426	0.532	0.388
Kidney function								
Creatinine [μmol/L]	66.3 ± 21.2	66.3 ± 15.0	66.3 ± 18.6	63.6 ± 15.0	0.173	0.611	***0.037***	0.118
eGFR (CKD-EPI) [mL/min/1.73 m^2]	81.1 ± 16.6	79.1 ± 14.3	80.1 ± 15.5	83.5 ± 17.4	0.138	0.357	***0.009***	***0.034***
≥ 90 (stage G1) (n)	35 (35.7)	25 (26.6)	60 (31.3)	69 (40.8)				
60–89 (stage G2) (n)	51 (52.0)	59 (62.8)	110 (57.3)	85 (50.3)	0.309	0.563	0.096	0.157
< 60 (stage G3–G4) (n)	12 (12.2)	10 (10.6)	22 (11.5)	15 (8.9)				

IGM — impaired glucose metabolism; NGT — normal glucose tolerance; MI — myocardial infarction; SBP — systolic blood pressure; DBP — diastolic blood pressure; ABI — ankle/brachial index; CIMT — carotid intima/media thickness; AAD — abdominal aorta diameter

Table 3. Metabolic parameters of the study population divided into four groups. The results are presented as mean and standard deviation (SD) or number and percentage. Significant differences in bold italic

Variable	Diabetes (A) n = 98	Prediabetes (B) n = 94	IGM (C) n = 192	NGT (D) n = 172	P value			
	Mean ± SD or n (%)	Mean ± SD or n (%)	Mean ± SD or n (%)	Mean ± SD or n (%)	A *vs.* B	A *vs.* D	B *vs.* D	C *vs.* D
Total cholesterol [mmol/L]	5.00 ± 1.17	5.85 ± 1.20	5.41 ± 1.25	5.73 ± 1.28	***< 0.001***	***< 0.001***	0.572	***0.003***
HDL cholesterol [mmol/L]	1.64 ± 0.52	1.65 ± 0.37	1.64 ± 0.45	1.78 ± 0.45	0.390	***0.003***	***0.020***	***0.001***
Non-HDL cholesterol [mmol/L]	3.36 ± 1.20	4.20 ± 1.23	3.77 ± 1.28	3.98 ± 1.27	***< 0.001***	***< 0.001***	0.181	***0.033***
LDL cholesterol [mmol/L]	2.64 ± 1.07	3.46 ± 1.10	3.05 ± 1.16	3.42 ± 1.15	***< 0.001***	***< 0.001***	0.636	***< 0.001***
Triglycerides [mmol/L]	1.63 ± 1.00	1.54 ± 0.61	1.58 ± 0.83	1.28 ± 0.58	0.940	***< 0.001***	***< 0.001***	***< 0.001***
Dyslipidemia (TG >1.7 mmol/L and/or HDL < 1.3 mmol/L) (n)	39 (39.8)	40 (42.6)	79 (41.1)	41 (24.0)	0.809	***0.010***	***0.003***	***< 0.001***
Glucose [mmol/L]	7.81 ± 1.95	6.18 ± 0.61	7.00 ± 1.67	5.09 ± 0.42	***< 0.001***	***< 0.001***	***< 0.001***	***< 0.001***
TG/HDL ratio	2.72 ± 2.54	2.33 ± 1.27	2.53 ± 2.02	1.86 ± 1.26	0.855	***< 0.001***	***< 0.001***	***< 0.001***
VAI	5.42 ± 5.05	4.65 ± 2.77	5.04 ± 4.11	3.59 ± 2.55	0.838	***< 0.001***	***< 0.001***	***< 0.001***

IGM — impaired glucose metabolism; NGT — normal glucose tolerance; TG — triglycerides; VAI — visceral adiposity index

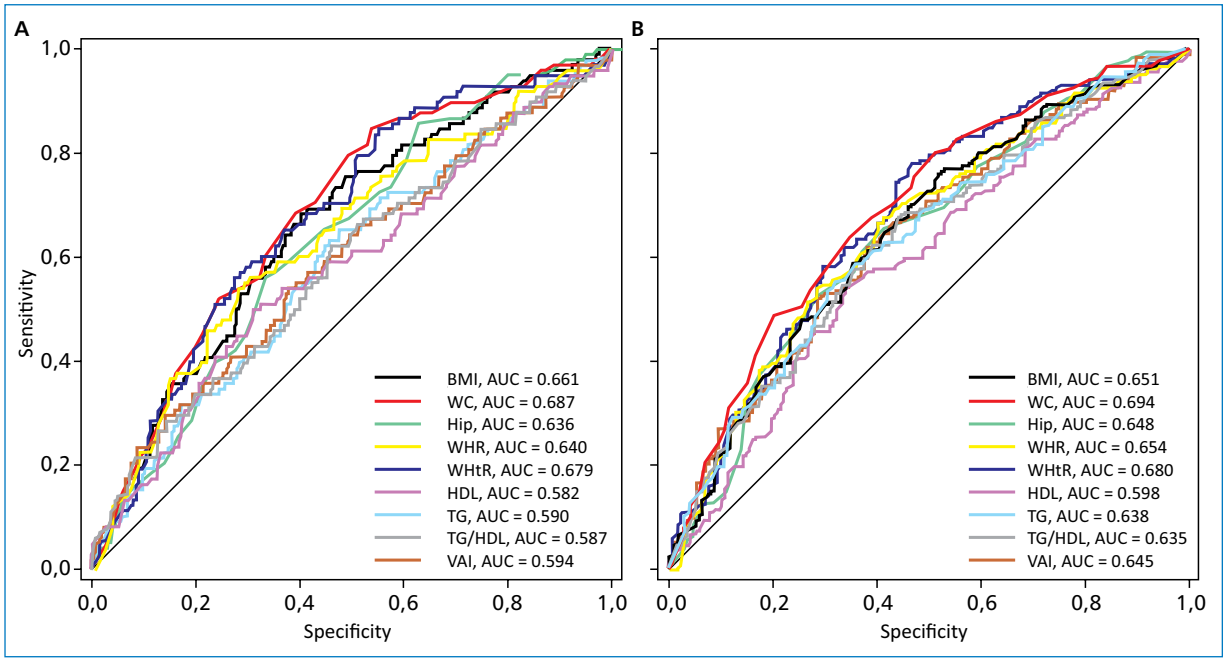

Figure 1. Receiver operating characteristic (ROC) curves and area under the curve (AUC) of anthropometric and metabolic parameters and indices associated with the prevalence of diabetes (**A**) and impaired glucose metabolism (**B**). BMI — body mass index; AUC — area under curve; WC — waist circumference; WHR — waist-to-hip-ratio; WHtR — waist-to-height ratio; HDL — high density lipoproteins; TG — triglycerides; VAI — visceral adiposity index

probability of having DM and over 30-fold higher probability of having IGM compared to NGT group, OR 10.04 (4.86–20.76), $P < 0.001$ and OR 31.04 (16.80––57.39), $P < 0.001$ respectively. However, glucose level > 5.5 mmol/L is a both MS component and a benchmark of IGM, and after adjustment to this variable these odds ratios decreased to OR 1.76 (1.07–2.89), $P = 0.034$ for DM and OR 2.10 (1.30–3.38), $P = 0.003$ for IGM.

All anthropometric and metabolic continuous variables significantly associated with abnormal glucose metabolism were then included in ROC analysis, separately for DM and IGM. The highest area under curve (AUC) for DM was found for WC, WHtR and BMI, $P < 0.001$ in all cases (Figure 1A), while for IGM there were WC, WHtR and WHR, $P < 0.001$ also in all cases (Figure 1B). Glucose level, as a diagnostic criterion for DM and prediabetes was excluded from these analyses.

We analyzed also odds ratios for variables significantly associated with the presence of DM or IGM. We assumed cut-off points for TG and HDL cholesterol level according to diagnostic criterion for MS [8], while for WC we took higher value, ≥ 88 cm, because 92.3% of all study participants had WC ≥ 80 cm. A cut-off point for BMI was ≥ 30 kg/m^2 (obesity), for WHR > 0.85 (abdominal obesity in women), for other variables cut-off points were taken from literature: VAI from Amato et al. [10], TG/HDL from Salazar et al., [11] and WHtR from Ashley & Gibson [12] or from ROC curve (hip circumference) (Figure 2).

In the backward stepwise regression analysis including all anthropometric and metabolic parameters and indices significantly associated with abnormal glucose metabolism, WHtR appeared to be the only significant predictor of having DM, $P < 0.001$, while WHtR and VAI were the only significant predictors of having IGM, $P < 0.001$ and $P = 0.005$ respectively.

Discussion

Our study revealed high prevalence of overt DM and prediabetes in elderly women living in a rural-urban community in central Poland. In this number 55.2% were previously un diagnosed. It is in line with data from other countries. In the United States prevalence of known DM in the elderly population is reaching 20.8%, and 4.4% have unknown DM [13]. In Canada prevalence of known DM among women aged 65–74 years is estimated to be 19.4% of females in this age range [14]. In the United Kingdom, in the age group 60–69 years, prevalence of DM exceeded 26% [15]. Also in China DM is prevalent in over 20% of elderly people, while IFG and/or IGT in roughly 25% [16]. Roughly, every one out of four people aged > 65 years suffers from DM. These data indicate how important epidemiological problem is DM in the elderly.

Both DM as well as IGT and/or IFG are associated with unfavorable clinical outcome including increased risk of cardiovascular disease (CVD) events and elevated CVD and all-cause mortality [17, 18]. In our study the

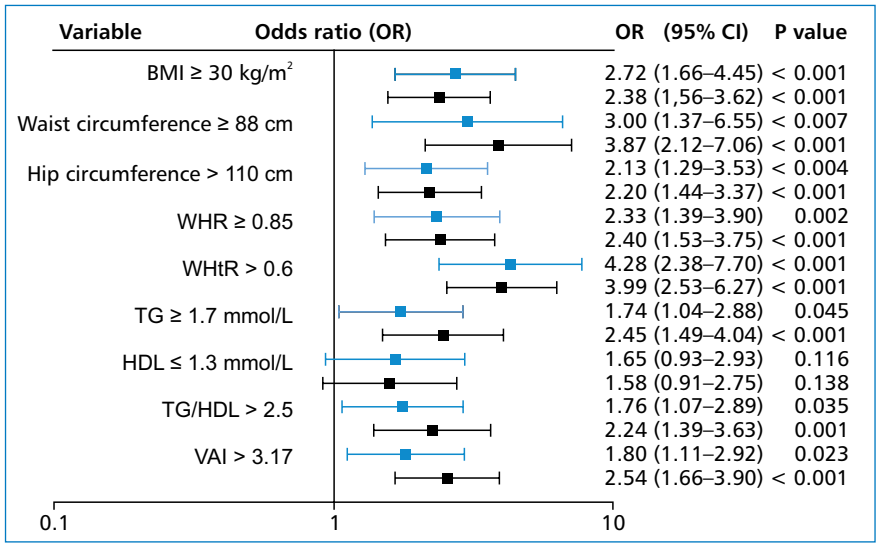

Figure 2. Odds ratios (OR) of anthropometric and metabolic variables for the probability of having diabetes mellitus (blue) or impaired glucose metabolism (black) in the univariate analysis. OR — odds ratio; CI — confidence interval; BMI — body mass index; WHR — waist-to-hip-ratio; WHtR — waist-to-height ratio; TG — triglycerides; HDL — high density lipoproteins; VAI — visceral adiposity index

history of myocardial infarction was significantly associated with overt DM. Interestingly, we revealed also association between lower abdominal aorta diameter in women with newly diagnosed DM. In men, Taimour et al. did not find such a relationship [19]. Thus, this finding requires further investigation. Significantly higher SBP and pulse pressure in women with overt diabetes together with lower abdominal aorta diameter can be considered as a clinical manifestation of the arterial stiffness in females with DM [20] (we did not perform direct measurements of pulse wave velocity and aortic characteristic impedance). In the Atherosclerosis Risk In Communities (ARIC) study low ABI was modestly but independently associated with diabetes incidence [21]. In our study ABI was not associated with any abnormal pattern of glucose metabolism. In the study by Gomez-Marcos et al. CIMT was related to HbA_{1c} and fasting, but not postprandial, plasma glucose [22]. We also revealed relationship between fasting glycemia and CIMT, while we did not measure HbA_{1c} in our study.

MS, non-surprisingly, demonstrated in our study significant relationship with DM and IGM. However, after adjustment to elevated glucose level, this relationship became much weaker. Significant relationship between different components of MS and DM was also found by other authors [16, 23]. In these studies the strongest indicators of DM prevalence were elevated TGs, low HDL cholesterol and elevated WC. In search of the best anthropometric indicator of elevated "early health risk" Ashley and Gibson indicate WHtR as a better indicator of this risk compared to BMI or WC alone [12]. In our study WHtR, although had slightly lower AUC than WC in the ROC curve analysis, it appeared to be significant predictor of prevalent DM and IGM in the backward stepwise analysis.

Amato et al. identified applicable indicator of visceral fat function based on WC, BMI, TGs and HDL cholesterol levels [9]. They called it Visceral Adiposity Index (VAI), and they developed the calculation formula separate for men and women. VAI can be considered as a predictor of cardio-metabolic risk, including diabetes [24, 25]. In our study females with abnormal glucose metabolism had significantly higher VAI score compared to women with NGT. The cut-off point for high metabolic risk (3.17) suggested by Amato et al. for Caucasian women aged ≥ 66 years [10] was in our study significantly associated with both DM and IGM prevalence and, together with WHtR, it was a predictor of prevalent IGM in the backward stepwise analysis.

Elevated TG/HDL cholesterol ratio is considered to be a useful tool in identifying men and women at high cardio-metabolic risk with a cut-off point at 2.5 for females and 3.5 for males [11]. In our study also this metabolic index was significantly higher in women with overt DM and prediabetes compared to females with NGT.

Type 2 DM is considered to be a preventable disease, both through the lifestyle as well as through the pharmacological interventions [26–28]. Early detection of IFG/IGT allows to introduce the efforts to prevent or at least delay diabetes development. Such strategy is not only beneficial for patients, but is also cost-effective

[29]. Early diagnosis of DM as well allows healthcare providers to initiate the treatment earlier in the natural history of diabetes, which gives a chance to avoid the long-term negative consequences of the disease, which was documented in the United Kingdom Prospective Diabetes Study (UKPDS) [30]. In the meta-analysis of 97 prospective studies involving 820,900 individuals, the onset of diabetes at the age of 65 was associated with a shortened life expectancy of almost 5 years [31]. Thus, screening focused on identifying people with abnormal glucose metabolism (in our study over 1/4 of women with DM were unaware of having diabetes and over 80% of women with prediabetes were unaware of this abnormality) can improve long-term prognosis of such persons, increase their life span and may be helpful in maintaining their quality of life. Moreover, it can be cost-effective.

Our study is not free from several limitations. The first one is a relatively small number of participants. The second one is its cross-sectional design, which did not allow us to determine a causal relationship of revealed associations. Also a number of women with the history of CVD events was too small to find more significant associations between analyzed variables and clinical outcomes other than myocardial infarction. Finally, our study was performed solely in Caucasian population. Thus, our results may not be fully applicable to other ethnic groups. On the other hand, our study included representative group of females in the age range 65–74 living in a rural-urban municipality, and a wide spectrum of analyzed variables allowed us to find several factors associated with glucose metabolism abnormalities in this population. We also found potential usefulness of anthropometric and metabolic indices other than BMI and waist circumference.

Conclusions

Diabetes and prediabetes are highly prevalent among women at early elderliness, and many of them were unaware of having these abnormalities.

Assessment of simple anthropometric measurements with the calculation of anthropometric indices seem to be helpful in identifying women at a high probability of having abnormal glucose metabolism. WHtR > 0.6 appeared to be the best predictor of DM, while WHtR > 0.6 and VAI > 3.17 were the best predictors of IGM.

Screening aimed at the detection of diabetes and prediabetes in women with central obesity and impaired lipid metabolism is highly reasonable, and it should be considered as a routine procedure to early diagnose and to early treat women at particularly high CVD risk.

Long-term observation of such a population is required to identify significant predictors of important clinical outcomes (major cardiovascular events, diabetes and cancer incidence, and all-cause death) in the future.

Conflict of interest

All the authors declare no conflict of interest in the field covered by this paper.

Acknowledgement

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REFERENCES

1. International Diabetes Federation. 2017. IDF Diabetes Atlas. Eighth Edition. http://diabetesatlas.org/resources/2017-atlas.html (dostęp z dnia 2019.07.15).
2. Walicka M, Chlebus M, Brzozowska M, et al. Prevalence of diabetes in Poland in the years 2010–2014. Clin Diabetol. 2016; 4(6): 232–237, doi: 10.5603/dk.2015.0031.
3. Sinclair A, Dunning T, Rodriguez-Mañas L. Diabetes in older people: new insights and remaining challenges. Lancet Diabetes Endocrinol. 2015; 3(4): 275–285, doi: 10.1016/S2213-8587(14)70176-7, indexed in Pubmed: 25466523.
4. American Diabetes Association. 4. Comprehensive medical evaluation and assessment of comorbidities: standards of medical care in diabetes — 2019. Diabetes Care. 2019; 42(Suppl 1): S34–S45, doi: 10.2337/dc19-S004, indexed in Pubmed: 30559230.
5. Central Statistical Office. Life expectancy tables of Poland 2016. Statistical Publishing Establishment. Warszawa 2017.
6. Levey AS, Stevens LA, Schmid CH, et al. CKD-EPI (Chronic Kidney Disease Epidemiology Collaboration). A new equation to estimate glomerular filtration rate. Ann Intern Med. 2009; 150(9): 604–612, doi: 10.7326/0003-4819-150-9-200905050-00006, indexed in Pubmed: 19414839.
7. Diabetes Poland. 2019 Guidelines on the management of diabetic patients. A position of Diabetes Poland. Clin Diabetol. 2019; 8(1): 1–95, doi: 10.5603/DK.2019.0001.
8. Alberti KG, Eckel RH, Grundy SM, et al. International Diabetes Federation Task Force on Epidemiology and Prevention, National Heart, Lung, and Blood Institute, American Heart Association, World Heart Federation, International Atherosclerosis Society, International Association for the Study of Obesity. Harmonizing the metabolic syndrome: a joint interim statement of the International Diabetes Federation Task Force on Epidemiology and Prevention; National Heart, Lung, and Blood Institute; American Heart Association; World Heart Federation; International Atherosclerosis Society; and International Association for the Study of Obesity. Circulation. 2009; 120(16): 1640–1645, doi: 10.1161/CIRCULATIONAHA.109.192644, indexed in Pubmed: 19805654.
9. Amato MC, Giordano C, Galia M, et al. AlkaMeSy Study Group. Visceral Adiposity Index: a reliable indicator of visceral fat function associated with cardiometabolic risk. Diabetes Care. 2010; 33(4): 920–922, doi: 10.2337/dc09-1825, indexed in Pubmed: 20067971.
10. Amato MC, Giordano C, Pitrone M, et al. Cut-off points of the visceral adiposity index (VAI) identifying a visceral adipose dysfunction associated with cardiometabolic risk in a Caucasian Sicilian population. Lipids Health Dis. 2011; 10: 183, doi: 10.1186/1476-511X-10-183, indexed in Pubmed: 22011564.

11. Salazar MR, Carbajal HA, Espeche WG, et al. 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. 2012; 109(12): 1749–1753, doi: 10.1016/j.amjcard.2012.02.016, indexed in Pubmed: 22449634.
12. Ashwell M, Gibson S. Waist-to-height ratio as an indicator of 'early health risk': simpler and more predictive than using a 'matrix' based on BMI and waist circumference. BMJ Open. 2016; 6(3): e010159, doi: 10.1136/bmjopen-2015-010159, indexed in Pubmed: 26975935.
13. National Center for Chronic Disease Prevention and Health Promotion. 2017. National Diabetes Statistics Report, 2017. Estimates of diabetes and its burden in the United States. https://www.cdc.gov/diabetes/pdfs/data/statistics/national-diabetes-statistics-report.pdf (dostęp z dnia 2019.07.15).
14. Public Health Agency of Canada. Diabetes in Canada: Facts and figures from a public health perspective. https://www.canada.ca/content/dam/phac-aspc/migration/phac-aspc/cd-mc/publications/diabetes-diabete/facts-figures-faits-chiffres-2011/pdf/facts-figures-faits-chiffres-eng.pdf (dostęp z dnia 2019.07.15).
15. Diabetes UK. 2016. Facts and Stats. https://diabetes-resources-production.s3-eu-west-1.amazonaws.com/diabetes-storage/migration/pdf/DiabetesUK_Facts_Stats_Oct16.pdf (dostęp z dnia 2019.07.15).
16. Chen GY, Li L, Dai F, et al. Prevalence of and Risk Factors for Type 2 Diabetes Mellitus in Hyperlipidemia in China. Med Sci Monit. 2015; 21: 2476–2484, doi: 10.12659/MSM.894246, indexed in Pubmed: 26297334.
17. Liu L, Simon B, Shi J, et al. Impact of diabetes mellitus on risk of cardiovascular disease and all-cause mortality: Evidence on health outcomes and antidiabetic treatment in United States adults. World J Diabetes. 2016; 7(18): 449–461, doi: 10.4239/wjd.v7.i18.449, indexed in Pubmed: 27795819.
18. Huang Yi, Cai X, Chen P, et al. Associations of prediabetes with all-cause and cardiovascular mortality: a meta-analysis. Ann Med. 2014; 46(8): 684–692, doi: 10.3109/07853890.2014.955051, indexed in Pubmed: 25230915.
19. Taimour S, Zarrouk M, Holst J, et al. Aortic diameter at age 65 in men with newly diagnosed type 2 diabetes. Scand Cardiovasc J. 2017; 51(4): 202–206, doi: 10.1080/14017431.2017.1319971, indexed in Pubmed: 28434285.
20. Prenner SB, Chirinos JA. Arterial stiffness in diabetes mellitus. Atherosclerosis. 2015; 238(2): 370–379, doi: 10.1016/j.atherosclerosis.2014.12.023, indexed in Pubmed: 25558032.
21. Hua S, Loehr LR, Tanaka H, et al. Ankle-brachial index and incident diabetes mellitus: the atherosclerosis risk in communities (ARIC) study. Cardiovasc Diabetol. 2016; 15(1): 163, doi: 10.1186/s12933-016-0476-4, indexed in Pubmed: 27923363.
22. Gomez-Marcos MA, Gomez-Sanchez L, Patino-Alonso MC, et al. MARK Group. Association between markers of glycemia and carotid intima-media thickness: the MARK study. BMC Cardiovasc Disord. 2016; 16(1): 203, doi: 10.1186/s12872-016-0380-6, indexed in Pubmed: 27793100.
23. Giannini S, Bardini G, Dicembrini I, et al. Lipid levels in obese and nonobese subjects as predictors of fasting and postload glucose metabolism. J Clin Lipidol. 2012; 6(2): 132–138, doi: 10.1016/j.jacl.2011.09.005, indexed in Pubmed: 22385546.
24. Wang Y, He S, He J, et al. Predictive value of visceral adiposity index for type 2 diabetes mellitus: A 15-year prospective cohort study. Herz. 2015; 40 Suppl 3: 277–281, doi: 10.1007/s00059-014-4175-1, indexed in Pubmed: 25410470.
25. Dereziński T, Zozulińska-Ziółkiewicz D, Uruska A, et al. Visceral adiposity index as a useful tool for the assessment of cardiometabolic disease risk in women aged 65 to 74 living in central Poland. Diabetes Metab Res Rev. 2018; 34(8): e3052, doi: 10.1002/dmrr.3052, indexed in Pubmed: 30064156.
26. Diabetes Prevention Program Research Group. Long-term safety, tolerability, and weight loss associated with metformin in the Diabetes Prevention Program Outcomes Study. Diabetes Care. 2012; 35(4): 731–737, doi: 10.2337/dc11-1299, indexed in Pubmed: 22442396.
27. Ley SH, Hamdy O, Mohan V, et al. Prevention and management of type 2 diabetes: dietary components and nutritional strategies. Lancet. 2014; 383(9933): 1999–2007, doi: 10.1016/S0140-6736(14)60613-9, indexed in Pubmed: 24910231.
28. Balk EM, Earley A, Raman G, et al. Combined Diet and Physical Activity Promotion Programs to Prevent Type 2 Diabetes Among Persons at Increased Risk: A Systematic Review for the Community Preventive Services Task Force. Ann Intern Med. 2015; 163(6): 437–451, doi: 10.7326/M15-0452, indexed in Pubmed: 26167912.
29. Breeze PR, Thomas C, Squires H, et al. The impact of Type 2 diabetes prevention programmes based on risk-identification and lifestyle intervention intensity strategies: a cost-effectiveness analysis. Diabet Med. 2017; 34(5): 632–640, doi: 10.1111/dme.13314, indexed in Pubmed: 28075544.
30. Stratton IM, Adler AI, Neil HA, et al. Association of glycaemia with macrovascular and microvascular complications of type 2 diabetes (UKPDS 35): prospective observational study. BMJ. 2000; 321(7258): 405–412, doi: 10.1136/bmj.321.7258.405, indexed in Pubmed: 10938048.
31. Rao Kondapally Seshasai S, Kaptoge S, Thompson A, et al. Emerging Risk Factors Collaboration. Diabetes mellitus, fasting glucose, and risk of cause-specific death. N Engl J Med. 2011; 364(9): 829–841, doi: 10.1056/NEJMoa1008862, indexed in Pubmed: 21366474.