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# *A comparative evaluation of waist circumference, waist-to-hip ratio, waist-to-height ratio and body mass index as indicators of impaired glucose tolerance and diabetes mellitus type 2 risk factors*

Obesity can be defined as an excessive accumulation of fat tissue, which worsens the health status and general feeling of a man (3). It is recognized as one of the most serious factors of insulin resistance development and consequently of impaired glucose tolerance (IGT) and diabetes mellitus type 2 (DM2) – 2,4.

A number of anthropometric indices are used for indirect evaluation of fat tissue accumulation: body mass index (BMI), waist circumference (WC), waist to height ratio (WHtR) and waist to hip ratio (WHR), which is used for central obesity identification. The aim of this study is to determine which of these factors is the most advisable for the assessment of glucose tolerance disturbances risk in clinical practice. Plotting the ROC curve, we made a comparison of the diagnostic precision of the above tests. Simultaneously, we made an attempt to determine the cut-off points of these indices pointing to increased IGT and DM2 risk in the examined population (7).

## MATERIAL AND METHODS

The analysis was based on the data collected in the 1998–2001 period during the realization of the research project PBZ/018-11 commissioned by Minister of Health and Social Care: „Primary and Secondary Prevention and Their Impact On Epidemiological and Economical Indices In Diabetes Type 1 and 2 In The Polish Population", which was co-ordinated by Prof. Zbigniew Szybiński. The research involved 1965 people aged ≥ 35 years selected by double-stage random sampling from among the population of the Lublin town (8).

The examined (barefoot and in light clothes) were weighed on medical scales. The height was measured with a height ruler. Waist circumference (at the navel level) and hip circumference (at the level of greater trochanter of femoral bones) were measured with a measuring tape.

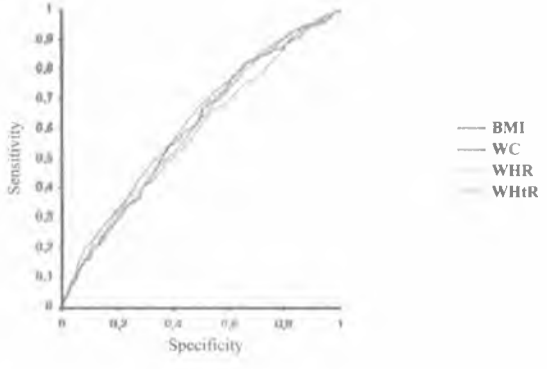
A sample of fasting blood was taken from the basilic vein in order to determine the whole blood glucose concentration level. Glicaemia was additionally measured 2 hours after a 75 g oral glucose load in the case of the patients without a firm earlier diabetes recognition and whose fasting glicaemia did not exceed 8 mmol/l (144mg/dl). Glucose concentration was

measured by means of Roche's Glucotrend glucometer. Glicaemia was assessed according to the WHO criteria from 1985 (11). DM2 was recognized when the fasting glicaemia in all vein blood was ≥ 6.7 mmol/l (120 mg/dl) and/or ≥ 10 mmol/l (180 mg/dl) in the 120$^{th}$ minute after an oral glucose load. IGT was recognized when the fasting glicaemia was < 6.7 mmol/l (120 mg/dl) and was ≥ 6.7 mmol/l (120 mg/dl) and < 10 mmol/l (180 mg/dl) in the 120$^{th}$ minute after an oral glucose load.

The evaluation of receiver operating characteristics (ROC) and Pearson's correlation test were used for statistical analysis (7).

## RESULTS

The relation between the studied indices and mean values of glucose concentration, fasting and after a 75g glucose load, was assessed by means of appropriate Pearson's correlation indices in patients who had not been previously submitted to antidiabetic treatment. Values of $p<0.05$ were considered to be statistically significant. As the studied indices can show various correlations depending on the sex or age, calculations were made for: the entire examined group; the group of men and the group of women; 3 age groups: 35–54, 55–69, 70 years and over.

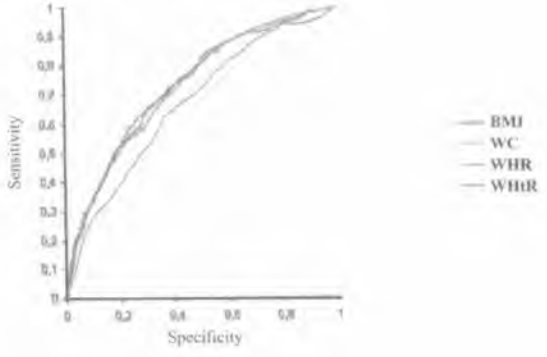



| Curve | Field | SE | p | 95% CI for Field |
|---|---|---|---|---|
| BMI | 0.601 | 0.0156 | <0.0001 | 0.571–0.632 |
| WC | 0.597 | 0.0155 | <0.0001 | 0.566–0.627 |
| WHR | 0.581 | 0.0160 | <0.0001 | 0.550–0.613 |
| WHtR | 0.621 | 0.0154 | <0.0001 | 0.591–0.652 |

Fig. 1. ROC IGT/NGT (normal glucose tolerance) curves

As one can observe, the growth of all the studied indices is correlated with the growth of glicaemia, especially after an oral glucose load. The weakest correlation is shown by WHR. WC showed the strongest correlation with fasting glicaemia (except for men, where closer relationship with BMI was observed) and the glicaemia after the load was most closely correlated with BMI and WHtR. After the 70$^{th}$ year of age, we observed the weakest correlation of fasting glicaemia and no statistically significant correlation with WHR. This age group,

however, was characterized by the highest correlation of glicaemia after an oral load (with an exception of BMI).




| Curve | Field | SE | p | 95% CI for Field |
|---|---|---|---|---|
| BMI | 0.731 | 0.0172 | <0.0001 | 0.698–0.765 |
| WC | 0.732 | 0.0164 | <0.0001 | 0.699–0.764 |
| WHR | 0.675 | 0.0175 | <0.0001 | 0.641–0.710 |
| WHtR | 0.731 | 0.0167 | <0.0001 | 0.698–0.763 |

Fig. 2. ROC DM2/NGT

Tab. 1. Assessment of correlation between BMI, WC, WHtR and WHR and mean glucose concentration values-fasting (Glu O) and in the 2 [nd] hour after an oral 75 g glucose load (Glu 2)

| Correlation | All | Sex | | Age (years) | | |
|---|---|---|---|---|---|---|
| | | women | men | 35-54 | 55-69 | 70+ |
| BMI : Glu 0 | 0.22* | 0.23* | 0.26* | 0.2* | 0.25* | 0.19* |
| WC : Glu 0 | 0.24* | 0.22* | 0.23* | 0.22* | 0.26* | 0.16* |
| WHR : Glu 0 | 0.18* | 0.14* | 0.15* | 0.2* | 0.14* | 0.02 NS |
| WHtR : Glu 0 | 0.18* | 0.21* | 0.22* | 0.15* | 0.19* | 0.14* |
| BMI : Glu 2 | 0.32* | 0.36* | 0.25* | 0.31* | 0.27* | 0.29* |
| W C: Glu 2 | 0.28* | 0.34* | 0.23* | 0.24* | 0.22* | 0.26* |
| WHR : Glu 2 | 0.17* | 0.25* | 0.14* | 0.12* | 0.1* | 0.15* |
| WHtR : Glu 2 | 0.32* | 0.36* | 0.27* | 0.28* | 0.23* | 0.31* |

* $p < 0.05$, NS – statistically insignificant correlation

Figures 1 and 2 present an analysis of ROC curves representing relations of BMI, WC, WHR and WHtR with IGT and DM2 (both previously diagnosed and newly diagnosed) respectively. A comparison of four anthropometric indices proved that all of them are characterized by a similar relation with the studied diseases. The indices in question show a

significantly weaker relation with IGT than with DM2. WHtR proved to have the highest diagnostic value in the IGT risk assessment IGT and WC in the assessment of DM2. Interval estimation demonstrated the presence of statistically significant differences between WHR and other indices in the ROC distribution for DM2.

Table 2. Cut-off points for IGT

| Sex | Index | Cut-off point | Sensitivity (%) | Specificity (%) | Effectiveness (%) |
|---|---|---|---|---|---|
| Women | BMI (kg/m$^2$) | 27.2 | 59.5 | 60.0 | 59.75 |
| | WC (cm) | 94 | 56.8 | 59.7 | 58.25 |
| | WHtR | 0.59 | 57.1 | 60.6 | 58.85 |
| | WHR | 0.91 | 55.2 | 60.1 | 57.65 |
| Men | BMI (kg/m$^2$) | 26.8 | 53.8 | 52.7 | 53.25 |
| | WC (cm) | 97 | 53.8 | 57.7 | 55.75 |
| | WHtR | 0.56 | 53.2 | 58.2 | 55.7 |
| | WHR | 0.96 | 54.9 | 55.7 | 55.3 |
| Total | BMI (kg/m$^2$) | 27.0 | 57.6 | 57.1 | 57.35 |
| | WC (cm) | 95 | 55.3 | 56.5 | 55.9 |
| | WHtR | 0.57 | 57.9 | 58.5 | 58.2 |
| | WHR | 0.93 | 56.3 | 53.5 | 54.9 |

Finding the best cut-off points of the anthropometric indices pointing to higher IGT (Tab. 2) and DM2 (Tab. 3) risks in the studied population was the next stage of our analysis. These points were set where both the values of sensitivity and specificity were at the maximum. The analysis was made: in the entire population; in a sex breakdown.

Table 3. Cut-off points for DM2

| Sex | Index | Cut-off point | Sensitivity (%) | Specificity (%) | Effectiveness (%) |
|---|---|---|---|---|---|
| Women | BMI (kg/m$^2$) | 29.2 | 70.2 | 69.9 | 70.05 |
| | WC (cm) | 97 | 68.7 | 67 | 67.85 |
| | WHtR | 0.62 | 68.7 | 72 | 70.35 |
| | WHR | 0.91 | 64.9 | 60.1 | 62.5 |
| Men | BMI (kg/m$^2$) | 27.9 | 63.4 | 63.5 | 63.45 |
| | WC (cm) | 99 | 64.1 | 63.2 | 63.65 |
| | WHtR | 0.57 | 66.2 | 64.9 | 65.55 |
| | WHR | 0.97 | 59.2 | 62.1 | 60.65 |
| Total | BMI (kg/m$^2$) | 28.5 | 67.0 | 67.3 | 67.15 |
| | WC (cm) | 98 | 66.7 | 65.6 | 66.15 |
| | WHtR | 0.59 | 66.7 | 67.7 | 67.2 |
| | WHR | 0.95 | 63.0 | 63.7 | 63.35 |

## DISCUSSION

Primary health care doctors should play a crucial role in detecting DM2 risk and its early recognition – more and more often it is going to be a well-educated family doctor.

Unfortunately, the load of daily work, occasional lack of even the most simple technical possibilities (lack of flexible but not stretchy scaled measuring tape, the so called, „tailor's measuring tape", lack of stiff height measuring ruler, lack of medical scales and a glucometer) but frequently also lack of medical knowledge cause a delay in the DM2 recognition. It is frequently recognized only wher its clear clinical symptoms appear and sometimes only when its "remote" complications are already present.

The research presented in this paper was carried out with the intention of making the daily work of primary health care doctor easier and more effective. It has been long known that DM2 risk grows along with the obesity level increase determined by the BMI growth. This fact was confirmed by our earlier studies (8).

BMI determination requires reliable body mass and height measurements and making quite a complicated – for some doctors – calculation. As we proved in this study, a simple, lasting more or less 10 seconds, measurement of waist circumference (WC) allows to precisely determine the DM2 risk.

There are a number of studies (5, 6, 10) which prove that this is the most useful index not only in IGT and DM2 diagnosis but also in diagnosis of other metabolic syndrome components such as arterial hypertension and dyslipidaemia and thus in the risk assessment of serious cardio-vascular diseases.

Our analysis confirms that the cut-off points of anthropometric indices in IGT and DM2 risk evaluation should be differentiated according to the sex, which can result from different distribution of the fat tissue in women and men. Berber (1), among others, pointed to this fact in his study. It should also be remembered, that they are characteristic of a particular population and a particular disease. Their value falls in older age groups (9).

## SUGGESTIONS

All the studied indices have a similar value for DM2 risk assessment. Waist circumference (WC) is especially noteworthy for the doctor's daily practice both because of its high diagnostic precision and exceptional simplicity of its determination.

The cut-off points of the studied indices should be differentiated according to sex.

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## SUMMARY

A number of anthropometric indices is used for evaluation of fat tissue accumulation. It is known, that together with increase of obesity increases prevalence of impaired glucose tolerance (IGT) and diabetes mellitus type 2 (DM 2). The aim of this study was to determine, which of following indices: body mass index (BMI), waist to hip ratio (WHR), waist to height ratio (WHtR) and waist circumference (WC) is the most suitable for the assessment of glucose tolerance disturbances' risk in clinical practice. Material and methods: The research involved an examination of 1965 people aged ≥ 35 years selected from the Lublin town population. Their body mass, height, waist and hip circumferences were measured. Fasting glicaemia and glucose concentration level in the 120$^{th}$ minute after 75g glucose oral load were determined in full vein blood. DM 2 and IGT were diagnosed according to the 1985 WHO criteria. The evaluation of receiver operating characteristics (ROC) and Pearson's correlation test were used for statistical analysis. Results: The increase of all the studied indices was correlated with the increase of glicaemia, especially after an oral glucose load. The weakest correlation was shown by WHR. WC showed the strongest correlation with fasting glicaemia (except for men, where closer relationship with BMI was observed). Glicaemia after the load was stronger correlated with BMI and WHtR. A comparison of indices made by the analysis of ROC proved that all of them are characterised by a similar relation with the studied diseases. The indices in question showed significantly weaker relation with IGT than with DM 2. WHtR proved to have the highest diagnostic value in the IGT risk assessment IGT and WC in the assessment of DM 2. Interval estimation demonstrated a presence of statistically significant differences between WHR and other indices in the ROC distribution for DM2. The best cut-off points suggested higher DM 2 risk we found were: BMI – 29,2 kg/m$^2$, WC – 97 cm, WHtR – 0,62, WHR – 0,91 for women and 27,9 kg/m$^2$, WC – 99 cm, WHtR – 0,57, WHR – 0,97 for men. Conclusions: All the studied indices have a similar value for DM 2 risk assessment. Waist circumference (WC) is especially noteworthy for the family doctor's practice both because of its high diagnostic precision and exceptional simplicity of its determination. The cut-off points of the studied indices should be differentiated according to sex.

Porównanie wartości wskaźnika masy ciała, stosunku obwodu talii do obwodu bioder, stosunku obwodu talii do wzrostu oraz obwodu talii jako wskaźników cukrzycy typu 2

Dla oceny kumulacji tkanki tłuszczowej, a więc stopnia otyłości, stosuje się różne wskaźniki. Jednocześnie wiadomo, że wraz z narastaniem otyłości zwiększa się częstość występowania upośledzonej tolerancji glukozy (IGT) i cukrzycy typu 2 (DM2). Celem pracy była ocena wartości indeksu masy ciała (BMI), stosunek masy ciała (kg) do kwadratu wysokości ($m^2$), stosunku obwodu talii do obwodu bioder (WHR), stosunku obwodu talii do wysokości (WHtR) i obwodu talii (WC) we wnioskowaniu o możliwości istnienia IGT i DM. Zbadano 1965 osób od 35 roku życia, mieszkających w Lublinie. Badanych ważono, mierzono ich wysokość, obwód talii (na wysokości pępka), obwód bioder, wykonywano pomiar glikemii we krwi żylnej pełnej na czczo i 2 godziny po doustnym obciążeniu 75g glukozy. DM2 i IGT rozpoznawano według kryteriów WHO z roku 1985. Ocenę statystyczną uzyskanych wyników przeprowadzono przy użyciu testu korelacji Pearsona i analizy krzywych ROC. Analizy dokonano dla zbadanej populacji w grupie kobiet i mężczyzn, w grupach wiekowych: 35–54, 55–69, 70 i więcej lat. Wielkość wszystkich wskaźników korelowała dodatnio z wielkością glikemii, zwłaszcza po obciążeniu glukozą. Z glikemią na czczo najsilniej korelował WC (z wyjątkiem mężczyzn, gdzie silniejszy związek był z BMI), z glikemią po obciążeniu glukozą najsilniej korelowały BMI i WHtR. Analiza krzywych ROC, ukazujących związek BMI, WHR, WHtR i WC z IGT i DM2, wykazała, że wszystkie te wskaźniki charakteryzuje podobny związek z badanymi schorzeniami. Stwierdzono obecność statystycznie istotnych różnic pomiędzy WHR i pozostałymi wskaźnikami w rozkładzie ROC dla cukrzycy. W diagnostyce DM2 najwyższą dokładność diagnostyczną wykazywał WC. Obliczone przez nas punkty odcięcia, najlepiej wskazujące na ryzyko nieprawidłowej tolerancji glukozy, różniły się w grupach płci i wynosiły dla DM2: BMI – 29,2 kg/$m^2$, WC – 97 cm, WHtR – O,62, WHR – 0,91 w grupie kobiet i 27,9 kg/$m^2$, WC – 99 cm, WHtR – O,57, WHR – 0,97 odpowiednio w grupie mężczyzn. W ocenie ryzyka DM2 wszystkie badane wskaźniki antropometryczne mają zbliżoną wartość, a szczególnie godny polecenia w codziennej praktyce lekarskiej jest obwód talii (WC) ze względu na wysoką dokładność diagnostyczną i wyjątkową prostotę oznaczania. Punkty odcięcia badanych wskaźników powinny być zróżnicowane w zależności od płci.