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Comparison of systolic and diastolic blood pressure with pulse pressure and mean arterial pressure for prediction of type 2 diabetes: The Isfahan Diabetes Prevention Study

Porównanie skurczowego i rozkurczowego ciśnienia tętniczego z ciśnieniem tętna i średnim ciśnieniem tętniczym w prognozowaniu rozwoju cukrzycy typu 2: badanie *Isfahan Diabetes Prevention Study*

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Abstract

Background: The aim of this study was to compare the ability of the systolic and diastolic blood pressure (BP), pulse pressure (PP), fraction PP (PPF) and mean arterial pressure (MAP) to predict progression to diabetes in non-diabetic first-degree relatives (FDRs) of patients with type 2 diabetes.

Material and methods: A total of 701 non-diabetic FDRs aged 20-70 in 2003 to 2005 were followed through to 2008 for the occurrence of type 2 diabetes mellitus. At baseline and through follow-ups, participants underwent a standard 75 g 2-h oral glucose tolerance test. Prediction of progression to type 2 diabetes was assessed using area under the receiver-operating characteristic (ROC) curves based upon measurement of PP, MAP, PPF, systolic and diastolic BP.

Results: Diabetes developed in 72 participants (10.3%) during the follow-up period. The incidence of type 2 diabetes was 3.4 per 100 person years in men and 4.9 in women. Systolic and diastolic BP and MAP were related to diabetes, but PP and PPF were not. Systolic and diastolic BP and MAP have similar associations with incident diabetes. Areas under the ROC curves were 0.582 for systolic, 0.589 for diastolic, 0.589 for MAP, 0.520 for PP, and 0.468 for PPF.

Conclusion: These results indicate that systolic and diastolic BP are as strong as MAP in predicting progression to diabetes. Increased BP may help identify FDRs of patients with type 2 diabetes at high risk for diabetes who are candidates for BP control.
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Key words: *first-degree relatives, pulse pressure, blood pressure, type 2 diabetes mellitus*

Streszczenie

Wstęp: Celem badania było porównanie wartości prognostycznej skurczowego i rozkurczowego ciśnienia tętniczego (BP), ciśnienia tętna (PP), cząstkowego ciśnienia tętna (PPF) i średniego ciśnienia tętniczego (MAP) w odniesieniu do rozwoju cukrzycy typu 2 u krewnych pierwszego stopnia pacjentów chorujących na tę chorobę.

Materiał i metody: W latach 2003–2005 włączono do badania 701 niechorujących na cukrzycę krewnych pierwszego stopnia osób chorych na cukrzyce typu 2 w wieku 20–70 lat i obserwowano ich do 2008 roku pod kątem rozwoju cukrzycy typu 2. Na początku badania i w ciągu okresu obserwacji u uczestników wykonywano standardowy 2-godzinny test doustnego obciążenia 75 g glukozy. Oceniano wartość pola pod krzywą ROC dla PP, MAP, PPF, skurczowego i rozkurczowego BP w prognozowaniu rozwoju cukrzycy typu 2.

Wyniki: W okresie obserwacji cukrzyca rozwinęła się u 72 uczestników badania (10,3%). Zapadalność na cukrzycę typu 2 wynosiła 3,4 na 100 osobolat u mężczyzn i 4,9 u kobiet. Skurczowe i rozkurczowe BP oraz MAP wiązały się z cukrzycą, lecz nie stwierdzono takiego związku w przypadku PP i PPF. Odnotowano podobne zależności między skurczowym i rozkurczowym BP oraz MAP a zapadalnością na cukrzycę. Pola powierzchni pod krzywymi ROC wynosiły 0,582 dla skurczowego BP, 0,589 dla rozkurczowego BP, 0,589 dla MAP, 0,520 dla PP i 0,468 dla PPF.

Wnioski: Powyższe dane wskazują, że skurczowe i rozkurczowe BP były równie silnie jak MAP związane z rozwojem cukrzycy. Podwyższone BP może być pomocne w identyfikowaniu krewnych pierwszego stopnia chorych na cukrzycę typu 2 obciążonych wysokim ryzykiem zachorowania na cukrzycę, dlatego należy u nich monitorować ciśnienie tętnicze. **(Endokrynol Pol 2011; 62 (4): 324–330)**

Słowa kluczowe: *krewni pierwszego stopnia, ciśnienie tętna, ciśnienie tętnicze, cukrzyca typu 2*

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Introduction

Type 2 diabetes mellitus continues to rise in prevalence worldwide. Diabetes prevention has become a major public health priority in both developed and developing nations. Therefore, there is great interest in identifying individuals at high risk of developing diabetes. The importance of arterial blood pressure (BP) as a predictor of type 2 diabetes, and the benefits of treatment, have been discussed.

However, BP can be divided into two other components: steady (mean arterial pressure or MAP) and pulsatile (pulse arterial pressure or PP) [1, 2]. Some studies have demonstrated that different BP components are predictors of type 2 diabetes [3–9].

However, no studies have compared the ability of different BP components to predict progression to diabetes.

Diabetes mellitus has been associated with an increase in arterial stiffness or a decrease in vascular distensibility [10–13]. Although it is plausible that diabetes mellitus increases PP by increasing arterial stiffness, there has been no extensive exploration of the direct relationship between PP and progression to diabetes. To date, one study has investigated the relationship between PP and the risk of developing diabetes in high risk hypertensive patients. This study postulated that the relationship between PP and diabetes could be attributable to increased arterial stiffness [14]. However, while Yasuno et al. [14] referred to PP as the independent risk factor for progression to diabetes in high-risk hypertensive patients, it is likely that genetic factors also influence risk of progression to diabetes. High BP and glucose metabolism risk factors [15–17] such as obesity are determined by genetic and early environmental influences. The first-degree relatives (FDRs) of patients with type 2 diabetes (which has a genetic basis) are at high risk of glucose intolerance and might be more appropriate for testing this hypothesis.

The aim of this study therefore was to compare the ability of systolic and diastolic BP, PP, fraction PP (PPF), and MAP to predict the incidence of type 2 diabetes in non-diabetic FDRs of patients with type 2 diabetes.

Material and methods

Participants and data collection

The Isfahan Diabetes Prevention Study (IDPS) is an ongoing cohort study in central Iran to assess the efficacy of intensive diet and exercise to prevent or delay the onset of type 2 diabetes mellitus in FDRs of patients with type 2 diabetes. The study was performed between 2003 and 2005. 2,368 (614 men and 1,754 women) of a consecutive sample of patients with type 2 diabetes attending clinics at Isfahan Endocrine and Metabolism Research Centre were included in the study. The participants completed laboratory tests including standard 75 g 2-hour oral glucose tolerance test (OGTT) and a questionnaire on their health status and on various potential risk factors for diabetes. Participants received follow-up tests according to a medical care standard in diabetes [18] to update information on demographic, anthropometric, BP, and lifestyle factors and on newly diagnosed diabetes. Accordingly, if OGTT was normal at baseline, repeat testing was carried out at least every three years. Otherwise, repeat testing was carried out annually. The IDPS baseline methods have been described in detail elsewhere [19]. The participants included siblings and children. The tenets of the Declaration of Helsinki were followed, institutional ethical committee approval was granted, and an informed consent form was signed by each participant.

Ascertainment of diabetes

Cases of diabetes were identified from baseline and follow-up OGTTs according to the criteria of the American Diabetes Association (ADA) [20]. Pregnant women were excluded. This study used data from 701 FDRs (150 men and 551 women) who were free of diabetes at registration, and had at least one subsequent review in the mean follow-up period of 2.3 (range 1–4) years. Attendees at the follow-up visit did not differ significantly from non-attendees regarding most baseline characteristics: age, gender, height, weight, body mass index (BMI), waist circumference (WC), hip circumference, waist-to-hip ratio (WHR) and levels of fasting plasma glucose (FPG), cholesterol, high-density lipoprotein (HDL) cholesterol, triglyceride, systolic BP or obesity. However, non-attendees had slightly lower diastolic BP (73.5 mm Hg versus 74.6 mm Hg, $p < 0.05$), HbA_{1c} (5.0% *vs*. 5.1%, $p < 0.05$), and plasma glucose (PG) at 30 min. (142.2 mg/dl *vs.* 147.0 mg/dl, $p < 0.01$), 60 min. (145.1 *vs*. 155.5, $p < 0.01$) and 120 min. (115.0 mg/dl *vs.* 127.8 mg/dl, $p < 0.01$), but higher levels of low-density lipoprotein (LDL) cholesterol (118.5 mg/dl versus 115.3 mg/dl, $p < 0.05$).

Covariates of interest collected at baseline and through follow-ups included age, gender, body size, HbA_{1c}, cholesterol, LDL, HDL, triglyceride and BP, family and personal medical history. The same methodology was used for both the prevalence and incidence studies. Participants reported to clinics in the morning after an overnight fast. Subjects were asked to abstain from vigorous exercise the evening before, and the morning of, the investigations. Smokers were encouraged to abstain from smoking in the morning of the investigations.

Firstly, on arrival at the clinic, the information given by the participants in the questionnaire as to their

family history was verified. Then, with the subjects in light clothes and without shoes, height, weight, waist and hip circumference were measured using standard apparatus. Resting BP was measured using a standard mercury column sphygmomanometer, with a cuff of appropriate size, in a seated position after subjects had been seated for ten minutes by the examining physician. The participants were explicitly asked not to cross their legs during measurement. FPG was measured using the glucose oxidase method. All five subjects underwent a standard OGTT (75 g glucose 2-hour) at baseline and at the follow-ups. Venous blood was sampled at fasting, 30, 60, and 120 min. after oral glucose administration. Plasma samples obtained after centrifugation were analysed the same day.

HbA_{1c} (measured by ion-exchange chromatography), total cholesterol, triglyceride, HDL, and LDL calculated by the Friedewald equation [21] were also assessed. All blood sample procedures were performed in the central laboratory of the Isfahan Endocrine and Metabolism Research Centre using the enzyme-linked method.

Definitions

BMI was measured as the ratio of weight (kg) to squared height (m^2), the latter being assessed at baseline only. Diabetes was defined if:

— two times FPG ≥ 126 or;
— one time 2-hour plasma glucose of ≥ 200 mg/dl or;
— self-report of diabetic treatment.

PP was defined as the difference between systolic and diastolic blood pressure. MAP was calculated as [(2 × diastolic BP) + systolic BP]/3. PPF [22] was calculated as PP divided by MAP.

Determination of diabetes incidence

Incidence of diabetes was expressed as the number of type 2 diabetes cases per 100 person-years of follow-up. The relevant period was considered to be the date of completion of the baseline examination between 2003 and 2005 until whichever came first out of:

— the occurrence of diabetes or
— the date of the last completed follow-up or
— death, or
— the end of the follow-up on 31 December, 2007.

Statistical analysis

Statistical methods used included the Student's t-test, chi squared test, and Cox's proportional hazards model. Different Cox's proportional hazards models were fitted to estimate the effect of systolic and diastolic BP, PP, PPF, and MAP on the risk of new-onset diabetes using SPSS for Windows (SPSS Inc., Chicago, IL, USA). Variables including age, BMI, total cholesterol and BP were entered the multiple-adjusted analyses as continuous variables, while gender was categorical.

All anthropometric or BP measures were not included simultaneously in regression analysis to avoid co-linearity that these independent variables may have. Adjustment for age and gender was examined in separate models. Age-adjusted means were calculated and compared using general linear models. The ability of PP, PPF, and MAP, systolic and diastolic BP values to predict the incidence of diabetes was examined by receiver operating characteristic (ROC) curve and their respective areas under the curve (AUC), in which sensitivity was plotted as a function of 1-specificity.

Areas under the ROC curves were compared by the algorithm developed by DeLong et al. [23]. All tests for statistical significance were two-tailed, and performed assuming a type I error probability of < 0.05.

Results

The mean (standard deviation or SD) age of patients was 42.7 (6.4) years. Patients enrolled had a mean (SD) HbA_{1c} of 5.1% (0.8), systolic BP of 115.1 (16.0) mm Hg, diastolic BP of 74.6 (12.1) mm Hg, MAP of 88.1 (12.3) mm Hg, PP of 40.5 (11.6) mm Hg and PPF of 4.7 (1.3) mm Hg at baseline. The prevalence of obesity (BMI ≥ 30) was 37.6%.

There was a significant correlation between systolic BP and diastolic BP ($r = 0.70$) and PP ($r = 0.66$) and between systolic BP and MAP ($r = 0.88$) ($p < 0.001$). The systolic BP and PPF were significantly but weakly correlated ($r = 0.19$, $p < 0.001$).

During 1,630 (354 men and 1,276 women) person-years of follow-up, 72 (11 men and 61 women) incident cases of type 2 diabetes occurred. The overall incidence of subsequent diabetes was 4.4 (95% CI: 3.5–5.6) per 100 person-years. The incidence rate was higher in women (4.9, 95% CI: 3.7–6.2 per 100 person-years) than men (3.4, 95% CI: 1.8–5.8), but the difference was not statistically significant.

Table I shows the group means (SE) and proportions for those FDRs who did and did not develop diabetes. Those who developed diabetes had higher systolic and diastolic BP, MAP, BMI, WC, hip circumference, FPG, plasma glucose at 30, 60 and 120 min., HbA_{1c}, cholesterol, LDL and were more obese at baseline.

The incidence of diabetes was 5.6% per year (95% CI: 3.4, 8.5) for participants in the highest quartile of systolic BP, and 3.3% per year (95% CI: 1.8, 5.4) for the lowest quartile. The equivalent incidences for diastolic BP were 6.5% (95% CI: 4.0, 9.8) and 3.4% per year (95% CI: 2.2, 4.9). For individuals in the highest quartile of PP, the incidence of diabetes was 4.2% (95% CI: 2.4, 6.8) and for the lowest quartile 3.9% per year (95% CI: 2.3, 6.2).

Table I. *Age, age-adjusted means [SE] and proportions of selected baseline characteristics between 72 first-degree relatives of patients with type 2 diabetes who did, and 629 who did not, develop diabetes*

Tabela I. *Wiek, skorygowane względem wieku średnie (SE) i odsetkowe wartości dla wybranych parametrów w grupie 72 krewnych pierwszego stopnia, u których rozwinęła się cukrzyca i 629 krewnych pierwszego, którzy nie zachorowali na cukrzycę*

Variables	Developed diabetes Mean (SE)	Not developed diabetes Mean (SE)	Difference (95% CI)
Age [years]	43.6 [0.74]	42.6 [0.25]	1.0 [–0.56, 2.56]
BMI [kg/m^2]	30.9 (0.48)	28.9 (0.16)	2.0 (1.11, 3.09)***
Waist circumference [cm]	92.0 (1.04)	88.3 (0.35)	3.7 (1.72, 6.08)**
Hip circumference [cm]	111.7 (1.04)	107.7 (0.35)	4.0 (1.83, 6.17)***
Waist-to-hip ratio	0.82 (0.007)	0.82 (0.003)	0.00 (–0.01, 0.01)
Systolic BP [mm Hg]	119.5 (1.92)	114.6 (0.64)	4.9 (1.33, 9.47)*
Diastolic BP [mm Hg]	78.6 (1.45)	74.2 (0.49)	4.4 (1.58, 7.62)**
Pulse pressure [mm Hg]	41.4 (1.41)	40.4 (0.47)	1.0 (–1.65, 4.25)
Mean arterial pressure [mm Hg]	91.9 (1.49)	87.7 (0.50)	4.2 (1.47, 7.73)**
Fraction pulse pressure [mm Hg]	4.5 (0.17)	4.7 (0.05)	–0.2 (–0.53, 0.13)
Baseline fasting glucose [mg/dl]	106.1 (1.35)	93.3 (0.46)	12.8 (10.20, 15.80)***
Plasma glucose 30 min [mg/dl]	168.5 (3.72)	144.7 (1.23)	23.8 (16.9, 32.3)***
Plasma glucose 60 min [mg/dl]	193.8 (4.96)	151.2 (1.65)	42.6 (33.40, 54.20)***
Plasma glucose 120 min [mg/dl]	156.8 (4.11)	124.5 (1.38)	32.3 (24.50, 41.70)***
HbA_{1c} (%)	5.4 (0.12)	5.1 (0.04)	0.3 (0.05, 0.55)*
Triglyceride [mg/dl]	170.9 (12.34)	168.7 (4.19)	2.2 (–22.10, 29.10)
Cholesterol [mg/dl]	202.5 (4.83)	192.5 (1.62)	10.0 (1.01, 21.40)*
HDL cholesterol [mg/dl]	45.2 (1.40)	45.3 (0.48)	–0.1 (–3.02, 2.82)
LDL cholesterol [mg/dl]	123.0 [4.25]	114.4 [1.48]	8.6 [0.45, 18.40]*
Men	15.3%	21.7%	–6.4 [–15.30, 2.48]
Obesity [BMI ≥ 30]	53.5%	35.7%	17.8 [5.57, 30.00]**

Age-adjusted means were calculated using general linear models. The difference in the mean or percentage o f the variables between diabetes and no diabetes. *p < 0.05, **p < 0.01, ***p < 0.001. CI= Confidence interval

The incidence of diabetes was 5.7% (95% CI: 3.6, 8.5) for individuals in the highest quartile of MAP, and for the lowest quartile 2.6% (95% CI: 1.2, 4.6). The association between systolic and diastolic BP and MAP and type 2 diabetes was similar and the risk of type 2 diabetes increased with increasing quartiles of these three BP indicators. In age-adjusted and gender-adjusted analysis comparing the associations in the highest to the lowest quartile, the MAP relative risk was slightly stronger than the systolic or diastolic hazard ratios (Table II). Age-, gender-adjusted hazard ratio shows diastolic BP and MAP is associated with diabetes only in higher quartiles. The associations were attenuated after adjustment for body mass index, suggesting it is the key intermediate factor in the pathway between BP and diabetes (data not shown).

The areas under the ROC curves for incidence of type 2 diabetes were 0.582 (95% CI: 0.510–0.654), 0.589 (95% CI: 0.519–0.660), 0.520 (95% CI: 0.447–0.594), 0.589 (95% CI: 0.518–0.661) and 0.468 (95% CI: 0.398–0.538) for the systolic, diastolic, PP, MAP and PPF respectively (Figure 1). Systolic, diastolic and MAP were significant predictors for future risk of type 2 diabetes ($p < 0.05$). MAP had an area similar to systolic and diastolic BP.

Discussion

The predictive value of different BP components is important because type 2 diabetes mellitus is associated with considerably increased risk of cardiovascular disease.

This study shows for the first time that the discriminatory ability of systolic and diastolic BP is as good as that of MAP, further emphasising the utility of systolic or diastolic BP alone in predicting diabetes. PP is a weaker diabetes risk predictor than systolic and diastolic BP and MAP. No study has previously compared the association between different components of BP and risk of diabetes.

A few studies have so far analysed the relationship between BP and incidence of diabetes [3–9].

Table II. *Incidence rates and relative risks (95% CI) of type 2 diabetes by quartiles of blood pressure parameters, the Isfahan Diabetes Prevention Study, 2003–2008*

Tabela II. *Zapadalność i ryzyko względne (95% CI) zachorowania na cukrzycę typu 2 w zależności od kwartyli wartości ciśnienia tętniczego w badaniu Isfahan Diabetes Prevention Study, 2003–2008*

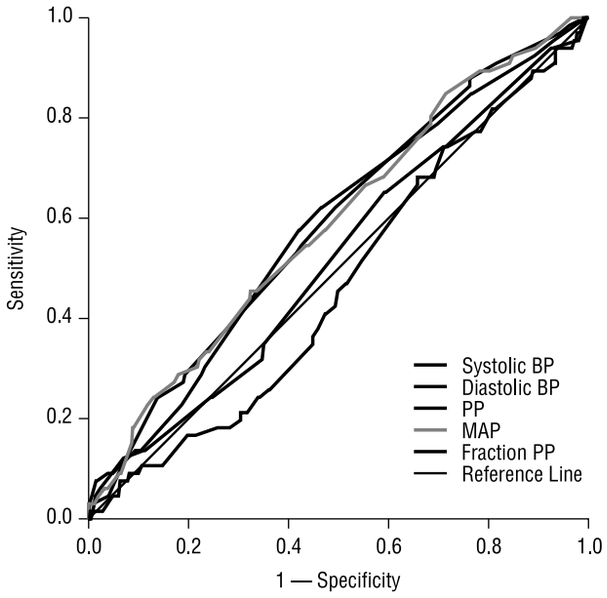
Variables	Cases (no.)	Incidence/100 person-year	Age-adjusted hazard ratio (95% CI)	Age and gender adjusted hazard ratio (95% CI)*
Systolic blood pressure				
1st quartile (< 100.5 mm Hg)	14	3.26	1.00	1.00
2nd quartile (100.5–110.0 mm Hg)	11	3.08	0.94 (0.43, 2.08)	0.96 (0.44, 2.13)
3rd quartile (110.1–120.0 mm Hg)	21	5.44	1.59 (0.80, 3.16)	1.64 (0.83, 3.27)
4th quartile (> 121.0 mm Hg)	20	5.56	1.62 (0.81, 3.25)	1.68 (0.83, 3.38)
Diastolic blood pressure				
1st quartile (< 70.0 mm Hg)	25	3.36	1.00	1.00
2nd quartile (70.0–75.0 mm Hg)	5	4.38	1.28 (0.79, 3.34)	1.33 (0.51, 3.48)
3rd quartile (75.1–80.0 mm Hg)	18	4.88	1.41 (0.77, 2.59)	1.40 (0.76, 2.58)
4th quartile (> 80.0 mm Hg)	20	6.45	1.86 (1.03, 3.35)*	1.93 (1.07, 3.49)**
Pulse pressure				
1st quartile (< 30.0 mm Hg)	17	3.92	1.00	1.00
2nd quartile (30.0–40.0 mm Hg)	26	4.62	1.20 (0.65, 2.22)	1.18 (0.64, 2.17)
3rd quartile (40.1–45.0 mm Hg)	7	4.46	1.12 (0.47, 2.71)	1.17 (0.48, 2.82)
4th quartile (> 45.0 mm Hg)	16	4.23	1.04 (0.52, 2.06)	1.02 (0.79, 3.04)
Mean arterial pressure				
1st quartile (< 80.0 mm Hg)	10	2.55	1.00	1.00
2nd quartile (80.0–87.0 mm Hg)	18	4.65	1.78 (0.82, 3.87)	1.82 (0.84, 3.96)
3rd quartile (87.1–94.0 mm Hg)	16	4.36	1.65 (0.74, 3.65)	1.66 (0.75, 3.69)
4th quartile (> 94.0 mm Hg)	22	5.70	2.11 (0.99, 4.50)	2.20 (1.03, 4.71)**
Fraction pulse pressure				
1st quartile (< 3.8 mm Hg)	17	3.83	1.00	1.00
2nd quartile (3.8–4.5 mm Hg)	19	5.71	1.46 (0.76, 2.81)	1.44 (0.75, 2.78)
3rd quartile (4.6–5.4 mm Hg)	18	4.64	1.20 (0.62, 2.33)	1.18 (90.61, 2.30)
4th quartile (> 5.4 mm Hg)	12	3.27	0.84 (0.40, 1.77)	0.83 (0.78, 3.02)

*Hazard ratios (with 95% CI) calculated by Cox proportional hazard model; **p <0.001. CI= Confidence interval

Similar to our findings, the Women's Health Study [3], the Atherosclerosis Risk in Communities Study [4], the Netherlands study [5] and the German study [6] found that high BP was associated with an increased risk of type 2 diabetes. Gress et al. [8] found that subjects with hypertension had a relative risk of 2.3 of developing type 2 diabetes compared to subjects without hypertension. Almgren et al. [24] found that treated hypertensive patients are at an increased risk of type 2 diabetes, and that this is associated with a high risk for cardiovascular complications and mortality. One study found that the risk of developing type 2 diabetes increases with increasing number of metabolic abnormalities, but that BP per se was not independently associated with new-onset diabetes [7].

On the basis of our overall findings, systolic and diastolic BP and MAP have approximately the same predictive discrimination. Because systolic and diastolic BP is strongly correlated with MAP, they are unlikely to yield different answers and the three measures yield similar information, with the correlation coefficient above 0.80.

The association between PP and risk for diabetes in the FDRs of patients with type 2 diabetes has not been elucidated. A recent study of the association between PP and the incidence of type 2 diabetes in high-risk hypertensive patients found PP was an independent predictor for new-onset diabetes and postulated that the relationship between PP and diabetes could be attributable to increased arterial stiffness [14]. The lack of relationship between PP and diabetes risk in the present



Area under the curve (95% CI)	
Systolic blood pressure	0.582 (0.510, 0.654)
Diastolic blood pressure	0.589 (0.519, 0.660)
Mean arterial pressure	0.589 (0.518, 0.661)
Pulse pressure	0.520 (0.447, 0.594)
Fraction pulse pressure	0.468 (0.398, 0.538)

Figure 1. *Receiver operating characteristic curves for systolic and diastolic BP, mean arterial pressure (MAP), pulse pressure (PP) and fraction PP for predicting type 2 diabetes in non-diabetic first-degree relatives of patients with type 2 diabetes. Estimates of the areas under the ROC curves and their 95% confidence intervals are shown*

Rycina 1. *Krzywe ROC dla ciśnienia skurczowego i rozkurczowego, średniego ciśnienia tętniczego (MAP) i cząstkowego ciśnienia tętna (PP) w prognozowaniu rozwoju cukrzycy typu 2 u krewnych pierwszego stopnia osób chorych na cukrzycę typu 2. Przedstawiono pola pod krzywą i 95-procentowe przedziały ufności*

study may be considered somewhat surprising. It is probably caused by the increasing importance of arterial stiffness with ageing. The association between age and PP is well described [25]. The younger age of our sample may explain why PP was not associated with diabetes. The significance of PP could be different and independent, but apparently is not correlated to the risk of diabetes. This awaits further investigation.

The mechanisms whereby high BP exerts negative effects on diabetes risk are not entirely clear. A possible explanation could be that elevated BP is associated with endothelial dysfunction, which is also related to insulin resistance and the development of type 2 diabetes [26]. On the other hand, elevated BP could be a marker for underlying insulin resistance, which constitutes a common soil for diabetes and cardiovascular disease [27]. Furthermore, research has demonstrated that high BP levels are accompanied by an elevation of inflammatory markers [28], which could also enhance the development of type 2 diabetes [29, 30]. Finally, studies have shown that pharmacological treatment of hypertension could lead to glucose intolerance and at least to the manifestation of type 2 diabetes [4, 24].

The strengths of our study include the fact that the sample consists of both men and women of a wide age range, and that the diagnosis of diabetes was based on standard OGTT and information on the potential determinants of glucose intolerance. Selection and information bias were unlikely because of the prospective design. Our study was limited to a cohort of individuals who are at increased risk of developing type 2 diabetes, as they had FDRs with the disease. This group of individuals will only increase further over time as the prevalence of diabetes increases worldwide [30]. Even though the study included more than 700 participants who were thoroughly examined and followed up, the follow-up period of two years may be controversial. Due to the still conflicting results in assessing diabetes prediction, a long-term follow-up (i.e. of 3–6 years) in a large cohort could clarify the situation even more. At follow-up, non-attendees of the entire population did not differ from attendees by major risk factors for progression to diabetes, although a difference too small to explain the high progression rate to diabetes in our study was seen in the mean levels of LDL, HbA_{1c}, and PG. The higher risk of developing type 2 diabetes in FDRs with high systolic and diastolic BP underlines the importance of preventing type 2 diabetes in these individuals. Several clinical trials have demonstrated that lifestyle [31–33] and pharmaceutical [31] interventions in high-risk individuals can prevent the development of diabetes, providing a rationale for the identification of high-risk subjects so as to institute early lifestyle or pharmacological interventions.

In conclusion, our study indicates that the systolic, diastolic and MAP are very highly correlated and likely to behave similarly in diabetes prediction. Further studies are needed to better understand the role of different BP components to predict diabetes. Increased BP may help identify FDRs of patients with type 2 diabetes at high risk for diabetes who are candidates for BP control.

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