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What if body fat percentage association with FINDRISC score leads to a better prediction of type 2 diabetes mellitus?

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Abstract

Introduction: Nowadays, the efforts regarding the prevention of type 2 diabetes mellitus (T2DM) are focused on decreasing overweight, obesity and visceral fat accumulation or percent body fat (PBF) risk factors. *Aim*: The aim of this study was to investigate whether use of bioelectrical impedance analysis (BIA) for measuring PBF could be a reliable method to improve risk assessment of T2DM. *Participants, Materials and Methods*: This cross-sectional study performed in 2016 enrolled 341 healthy medical students from western Romania, aged 18 to 44 years old, 143 females and 198 males. Anthropometric measurements, PBF (BIA machine InBody720®) determination, along with the Finnish Diabetes Risk (FINDRISC) assessment form, were performed for each participant. *Results*: 27.6% of the entire cohort was determined as being overweighed and 12% obese. FINDRISC score showed that 5% from the entire group have a moderate to very high risk to develop T2DM in the following 10 years. FINDRISC score was correlated with waist-to-hip ratio (WHR) and PBF showing strong and positive correlations to both parameters (WHR: 0.477, *p*<0.001; PBF: 0.561, *p*<0.001). *Discussions*: Our results indicate a stronger correlation between FINDRISC score with PBF compared to FINDRISC and WHR for the entire cohort, and for both males and females. *Conclusions*: We recommend PBF measured by BIA (respecting quality control procedures) as a potential parameter to be considered into the risk model predictions for T2DM, as it is an accessible and affordable tool to use in the primary level of healthcare.

Keywords: type 2 diabetes mellitus, risk, FINDRISC, young, percent body fat.

Introduction

Type 2 diabetes mellitus (T2DM) is a chronic, common metabolic disease characterized by hyperglycemia, insulin resistance, and relative deficiency of insulin [1]. Diabetic complications are often severe, leading to a significant reduction in the quality of life, which affects not only the individual, but also his family and society.

The etiology of T2DM is attributed to both lifestyle and genetic predisposition, acting in an independent fashion [2, 3]. More studies have indicated interactions between specific dietary elements and individual genetic susceptibility variants [4, 5]. To date, 48 single nucleotide polymorphisms identified in genome-wide association studies are linked to the genetic risk score for developing T2DM [3].

The prevalence of T2DM is increasing dramatically worldwide, parallel with obesity, especially among minority youth and young adults, being estimated that by 2025, 15% of the global population will be affected [6, 7]. More than that, overweight and obesity have now been widely recognized as the major epidemic of the 21st century [8]. Nowadays, prevention of T2DM should be achievable through the implementation of early and sustainable measures for prevention and early treatment of obesity, which is a major and modifiable risk factor.

A number of prospective and cross-sectional studies have shown that the association between insulin resistance, type 2 diabetes risk and regional adiposity argues that the visceral fat accumulation (VFA) has the most harmful metabolic effects [9, 10]. Patients with VFA develop adipose tissue dysfunction with hypoadiponectinemia, chronic low-grade inflammation, lipolysis stimulation and releasing of excess gluconeogenic substrates [non-esterified fatty acids (NEFA) and glycerol] to the liver. All these are resulting in inhibition of insulin signal transduction, hepatic and peripheral insulin resistance, and T2DM [11–13].

Several methods for determining VFA and percent body fat (PBF) are used in practice, such as body mass index (BMI), waist circumference (WC), waist-to-hip ratio

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(WHR), visceral adiposity index (VAI), and dual-energy X-ray absorptiometry (DEXA), but the gold standards remain magnetic resonance imaging (MRI) and computed tomography (CT) [14]. Rarely considered in practice, bioelectrical impedance analysis (BIA) for measuring the PBF is less expensive, easy to use, noninvasive and offers an advantage of portability. The controversies exist in the literature, the validity being affected by gender, age, disease state, level of fatness and ethnic backgrounds [15], but as long as all criteria and pre-test protocol are respected and quality control procedures are taken, measurements by BIA are well-accepted [16–18].

Regarding the additional risk factors for developing T2DM, there are several risk-scoring algorithms used worldwide. Non-laboratory risk scores are fast, simple and inexpensive and can be considered as screening methods but also as intervention tools as they provide direct and easy accessible information to the general practitioner and even directly to individual. Finnish Diabetes Risk (FINDRISC) score was proposed by a Finish research team, in 2003, following a study population on two independent samples, in 1987 and 1992, and a follow-up on 10 years. The samples included 6.6% of the population aged 25–64 years from North Karelia, Kuopio, and South-Western Finland, in 1987 (*National Population Register*), as well as from the Helsinki-Vantaa region, in 1992 (the FINRISK Studies). FINDRISC score prediction model expanded its utility abroad very fast, being used nowadays in many countries around Europe and beyond [19, 20].

Aim

The aim of this study was to investigate whether BIA for measuring body percent fat in a healthy medical students' population could be a reliable method to improve risk estimation for developing T2DM.

Participants, Materials and Methods

This cross-sectional study performed in 2016 enrolled 341 young healthy medical voluntary students from "Victor Babeş" University of Medicine and Pharmacy, Timişoara, Romania, who agreed to join the study and gave written informed consent. All procedures were approved by "Victor Babeş" University of Medicine and Pharmacy Ethics Committee and complied with Declaration of Helsinki.

Exclusion criteria were represented by pregnant participants, those who had a history of major surgery on their extremities, malignancies, stage IV chronic kidney disease or renal replacement therapy, liver cirrhosis with ascites, heart failure with peripheral edema, or severe hypothyroidism, fever resulting from an active infection or inflammation, those receiving systemic steroid treatment, those suffering severe dehydration and those having chronic medication (*e.g.*, statins, diuretics, and other medication that might affect water distribution in body).

Prior to the study, all participants were asked to present to the evaluation before midday, fasten overnight for at least eight hours before having the measurements, emptying bladder just before the test, to restrict alcohol and caffeine-containing drinks as well as to refrain themselves from intense physical activity within 24 hours.

Anthropometry

Anthropometric measurements were performed by a single examiner. Weight, height, WC and hip circumference were measured with footwear removed and in light clothing, using the same devices. BMI was calculated as weight (kg) divided by height squared (m^2) and WHR according to the international criteria [21]. All measurements fulfilled quality control criteria.

PBF measurements

Abdominal VFA was measured using a tetrapolar multifrequency BIA machine (InBody720®) for each individual. Operation environment was established according to recommendations: temperature range 5~35^{0}C, relative humidity 30~75%, atmospheric pressure range 70~106 kPa [22, 23].

Coordinated by an experienced supervisor, subjects had to stand on the platform of the device with both arms apart from the body and both feet on the right spots on the platform. Both hands were held at a 45 degrees angle away from the body. Age and gender information was written into the machine software. The device uses 1, 5, 50, 250, 500 kHz, and 1 MHz frequencies to analyze intracellular and extracellular fluid values and water content. The electrodes connected to the footpads send a low electrical current through the body. The PBF was displayed, which was calculated from prediction equations provided by the manufacturer.

FINDRISC score assessment form

Participants were asked to fill in the FINDRISC score assessment form after all items were explained. Assistance was offered in case of need. The items (8) were the classic ones from FINDRISC T2DM risk assessment form: age, BMI, WC measured below ribs, daily physical activity, the frequency of eating vegetables, fruit or berries, frequency of taking medication for high blood pressure, history of hyperglycemia, familial history of diabetes (type 1 or type 2). Each answer to every item is assigned to weighted scores corresponding to the increase of risk for T2DM correlated to the value in the regression model of the original cohort. The final score is the sum of the scores from eight questions and ranges from 0 to 26.

The interpretation of the assessment form was performed after cumulating the total number of points corresponding to each item as following:

- Lower than 7: Low – estimated one in 100 will develop disease;
- 7–11: Slightly elevated – estimated one in 25 will develop disease;
- 12–14: Moderate – estimated one in six will develop disease;
- 15–20: High – estimated one in three will develop disease;
- Higher than 20: Very high – estimated one in two will develop disease [19].

Data analysis

Statistical analysis was performed using IBM *Statistical Package for the Social Sciences* (SPSS) Statistics 23 software and a two-tailed p-value <0.05 was considered significant. To describe the cohort, data was tested for normal distribution. All 341 registrations were valid for the entire data. Results were compared between females and males using independent samples *t*-test. The expected value was calculated and a cut-off point of 5 was considered. Spearman's correlation coefficients were applied to establish the correlations between variables.

Results

A total of 341 healthy medical students, adults, 143 females and 198 males, aged between 18 to 44 years old were recruited into the study. The anthropometric measures of the participants, along with their mean PBF values as determined by BIA are summarized in Table 1.

Table 1 – *Cohort description*

Gender		Height [cm]	Weight [kg]	BMI [kg/m²]	Age [years]	Waist-to-hip ratio	Percent body fat [%]
Males (*n*=198)	*Median*	176	78.5	25.181	20	0.86	19.9
	Percentage 25	173	67.75	22.057	19	0.82	14.3
	Percentage 50	176	78.5	24.181	20	0.86	19.9
	Percentage 75	180	90.25	28.608	22	0.89	26.45
Females (*n*=143)	*Median*	164	57	21.048	20	0.79	29
	Percentage 25	159	51	19.362	19	0.77	23.8
	Percentage 50	164	57	21.048	20	0.79	29
	Percentage 75	168	67	24.447	22	0.82	33.5

BMI: Body mass index.

The variables that did not have normal distribution are presented using median and quartiles. There were no differences between males and females in mean ages (20 years old). 27.6% of the entire cohort was determined as being overweighed and 12% obese (Figure 1).

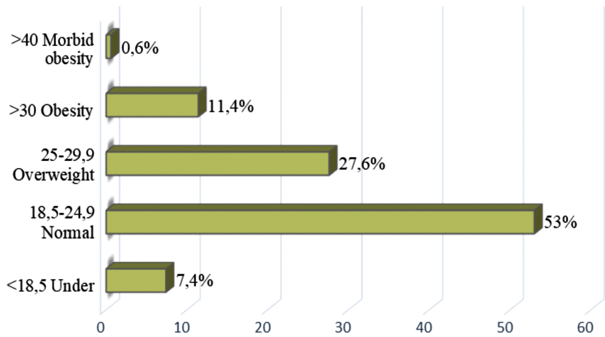

Figure 1 – *Overweight and obesity (body mass index – BMI) distribution in the analyzed cohort (%).*

As for age–BMI correlation, cohort repartition was the following: one male and one female aged 20 and 18 years old, respectively, representing 0.6%, with morbid obesity (BMI>40 kg/m^2); 39 individuals, representing 11.4%, with obesity (BMI between 30 and 40 kg/m^2), subgroup with 17.9% of individuals aged 18 and 19 years old, 74.5% aged between 20 and 29 years old and 7.6% aged between 30 and 44 years old; 94 individuals, representing 26.7%, with overweight (BMI between 25 and 29.9 kg/m^2), subgroup with 19.1% of individuals aged 18 and 19 years old, 70.2% aged between 20 and 29 years old and 10.7% aged between 30 and 44 years old. Gender distribution was the following: 13.9% of the female's group presented overweight and 7% obesity, while 37.4% of the males presented overweight and 15.7% obesity. The median BMI was 25.18 kg/m^2 for males and 21.04 kg/m^2 for females (*p*-value 0.002). Generally, men had also a larger WHR: the calculated median WHR for males was 0.86, while for females 0.79 (*p*-value 0.015). Women had higher PBF (29% compared to 20.9%).

The FINDRISC score was distributed as shown in Figure 2.

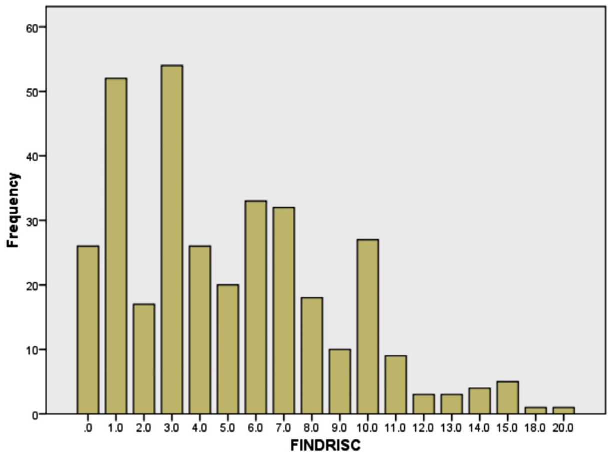

Figure 2 – *FINDRISC score distribution in the whole group of students. FINDRISC: Finnish Diabetes Risk.*

76.2% of the students have a low risk (estimated one in 100 will develop disease), 18.8% have a slightly elevated risk (estimated one in 25 will develop disease), 2.9% have a moderate risk (estimated one in six will develop disease), 1.8% have a high risk (estimated one in three will develop disease) and 0.3% have a very high risk for developing T2DM in the following 10 years (estimated one in two will develop disease), according to the assessment form criteria. Individuals found with moderate and high risk were advised to measure fasting blood glucose and for subsequent follow-up.

We analyzed the correlation between FINDRISC score and WHR for the entire cohort (Table 2) as control and we found a statistical high and positive correlation – 0.477, *p*<0.001 (WHR is an item of FINDRISC score). Further, we analyzed the correlation between FINDRISC score and PBF for the whole group of students and it was a statistical higher and positive correlation than the one with WHR (0.561, *p*<0.001). As for the subgroup of both genders, the correlation between FINDRISC score and both WHR and PBF was direct, very strong and statistically significant (*p*<0.001). By comparison, males had a stronger correlation regarding FINDRISC score and both WHR and PBF than females.

Table 2 – *Correlation between FINDRISC score and waist-to-hip ratio and percent body fat on entire cohort and males and females separately*

Spearman's *rho* correlation FINDRISC	Entire cohort (*n*=341)	Males (*n*=198)	Females (*n*=143)
Waist-to-hip ratio	0.477** (*p*=0.000)	0.671** (*p*=0.000)	0.451** (*p*=0.000)
Percent body fat	0.561** (*p*=0.000)	0.668** (*p*=0.000)	0.573** (*p*=0.000)

FINDRISC: Finnish Diabetes Risk; **Correlation is significant at the 0.01 level (two-tailed).

Discussions

Since a variety of etiological factors seem to contribute to T2DM, it is essential to elucidate the etiology in each patient, such as the main pathophysiological pathways, and detect potential prevention measures at an early stage. Despite global efforts in medicine and research for the prevention of T2DM, it was estimated a total number of 422 million adults living with diabetes in 2014 (90% with T2DM), compared to 108 million in 1980, reflecting an increase in associated risk factors such as obesity [6, 24].

According to *Global Health Observatory* (GHO) latest estimations based on self-reported anthropometry, prevalence numbers regarding overweight and obesity global burden are alarming and show that 39% (1.9 billion) of adults aged 18 years and over were overweight and 13% were obese, 41 million children less than the age of 5 were overweight or obese, and over 340 million children and adolescents aged 5–19 were overweight or obese [7, 24–26]. Our results consisting of a young group of subjects, the majority of them between 19 and 22 years old (73% of the entire cohort), provided a challenge in comparing with other studies as almost all found in the literature are structured in two main groups: children and adolescents, and adults. However, compared to the global prevalence, our group shows a significantly lower prevalence regarding overweight (27.6%) and a slightly lower percent of obesity (12%) [7]. But comparing to the estimated prevalence for Romania, which show that overweight in the adult population has reached 57.7% (64.3% for males and 51.1% for females) and obesity is much higher than the global report (22.5% for both genders, 23.4% for males and 21.6% for females), our results are significantly lower regarding both overweight and obesity [25]. A research in Romanian population subgroup 20–39 years old, published in 2016, found a prevalence of 27.2% for overweight and 20.9% for obesity overall. Males had a prevalence of overweight at 40.2% and of obesity at 20.7%, and overweight in females was lower at 14.8%, but obesity higher at 21.1%. Our results were similar to the other Romanian young cohort just regarding male and female overweight, but lower regarding obesity. These differences can be however explained by the extension of the age group to 39 years old and by the higher number of subjects [27].

For an effective risk assessment regarding T2DM, we have included into this study both the analyses of T2DM risk score and of the primary risk factors, which are overweight and obesity, but also the quantification of PBF.

The cohort of young healthy students was asked to fill in the FINDRISC assessment form as this scale is a trusted widely used in Europe and beyond. One limitation is linked to the FINDRISC score's validation among individuals less than 34 years old and more than 64 years old. This issues from the primary study design of FINDRISC score, which was applied to this range of ages and, even if used worldwide in various research works, it was not extended below [19, 20, 28]. Our results were however comparable to the prevalence of diabetes self-reported data from 2014 in Romania (4.8%) [29], being able to identify a percent of 5% from the entire group as having a moderate to very high risk to develop T2DM in the following 10 years. In a cross-sectional study conducted at Hashemite University in Zarqa, from Jordan, in 2014, it was reported a percentage of 66.9% students with low risk, 26.2% corresponding to a slightly elevated risk, 5.2% indicating a moderate risk and 1.8% at a high risk of diabetes. The minimum differences may be due to our relatively small cohort comparing to the one from Jordan, and also to ethnic particularities [30].

As the T2DM prevalence is growing among young population, teenagers and even children [31–33], we consider it is primordial to emphasize on preventive measures extended to these subgroup populations and to create tools or adapt the ones that already exist for adults. Among these measures, by controlling VFA, which may be improved by exercising and a healthy life style, consequences as adipose tissue dysfunction together with hypoadiponectinemia, chronic low-grade inflammation, lipolysis stimulation and releasing of excess gluconeogenic substrates to the liver can be reverted, as already determined by several research teams [34, 35].

Regarding VFA measurement, we preferred the use of BIA and PBF because of the real necessity in routine practice of a convenient and rapid to use tool. Also, there is already reported that taking into account only the overweight and obese individuals as being at risk for T2DM, an important proportion of non-obese (BMI<25 kg/m^2) persons that have a high PBF, and so a high risk for developing T2DM, is excluded [12]. An ultrasound measurement technique, also accessible in measuring the uncompressed subcutaneous adipose tissue thickness in children was proposed in 2017 by another research in Romania, with a good accuracy, however needing larger studies for validation [36].

BIA measurement of PBF is still controversial, and besides evident reasons like gender, age, disease state, level of fatness and ethnic backgrounds [15], two other explanations may be taken into account: first, 50 kHz of current can pass through extracellular and intracellular spaces, and hydration states can become a factor of error; second, standing position can influence the fluid distribution, and so the measurement of resistance [34, 35]. Some cross-sectional studies reported that BIA overestimates PBF [37, 38], whereas others have showed that BIA underestimates PBF [39, 40], by comparison to other methods considered as gold standard. Li *et al.* showed in 2003 in an interventional study on 189 subjects suggested that BIA provides a relatively accurate prediction of PBF in individuals with normal weight, overweight, or obesity after the end of weight-loss program, but less accurate prediction of PBF in obese individuals at baseline or weight change during the weight-loss intervention program [34]. Another study also using BIA for determining PBF, applied to 2336 Japanese men, in 2007, showed a decrease within one year of PBF in 53.1% of participants, increase in 33.2%, and no change in 13.7%. This data concluded that intervention strategies directed toward reduction of visceral fat could result in the reduction or disappearance of risks for atherosclerotic cardiovascular diseases [41]. As a general conclusion to almost all these works, BIA can be used as a reliable tool when DXA, MRI or CT are not available, especially within group estimations.

When taking into consideration that PBF is estimated in almost all risk prediction models for developing T2DM [FINDRISC, German DRS, Taiwanese MJ Longitudinal health checkup-based Population Database (MJLPD) DRS, Cambridge DRS, Framingham offspring study (FOS) DRS, SAHSNHW DRS, ARICNHW DRS I and II, Thai DRS, SAHSMA DRS, ARICAA DRS I, ARICAA DRS II and Indian DRS] just by a routine WC measurement, WHR and BMI calculation [20], we consider that adding PBF simply measured by BIA provides an important information for an improved risk assessment. This statement is sustained also by our findings related to the strong direct and positive correlation between FINDRISC score and PBF in the studied young healthy medical student population, both males and females. For validation, the analysis included a correlation of FINDRISC score with WHR, as WHR is a marker of abdominal obesity, which is already among FINDRISC score's items. Interestingly, our study found a stronger correlation between FINDRISC score and PBF compared to FINDRISC score and WHR for the entire cohort, but also for both males and females.

Conclusions

Considering the worldwide increasing prevalence of T2DM, along with overweight and obesity, despite global efforts for its prevention, all additional measures, which could improve results, should be considered. This study emphasizes on the reliability of PBF measurement by simple BIA when assessing T2DM risk. Our outcomes support a significant correlation between FINDRISC assessment prediction model and PBF, even stronger than between FINDRISC and WHR, one of its items. Thus, we recommend PBF measured by BIA (respecting quality control procedures) as a potential parameter to be considered into the risk model predictions for T2DM as it is an accessible and affordable tool to use in the primary level of healthcare.

Conflict of interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

Authors' contribution

Iulia-Elena Jurca-Simina and Iulius Jugănaru have equal contribution.

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