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Original Article

# Development of a novel anthropometry-based equation for diabetes risk prediction

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## Abstract

The increasing global burden of diabetes mellitus is a public health concern. In an attempt to stem the tide of the increasing prevalence of the disease, we decided to develop a diabetes risk prediction equation from precisely measured adiposity indices. We recruited 200 young adult Nigerians, 92 (46.0%) males and 108 (54.0%) females, aged 15–35 years, for this study. Participants filled out the Finnish diabetes risk scoring (FINDRISC) questionnaire and underwent anthropometric measurements following standard protocol. Pearson correlation and multiple regression analyses were utilized, while statistical significance was fixed at $p<0.05$. From the results, body mass index (BMI) correlated most significantly ($r=0.610$, $p<0.001$) with risk scores. We developed a diabetes risk prediction equation using the following adiposity indices; body mass index (BMI) ($r=0.610$, $p<0.001$), body adiposity index (BAI) ($r=0.561$, $p<0.001$), waist-to-height ratio (WHtR) ($r=0.557$, $p<0.001$) and waist circumference (WC) ($r=0.495$, $p<0.001$) while relying on the FINDRISC model for stratification of risk status. We recommend the utilization and validation of the developed prediction equation in other populations.

**Keywords:** prevalence, adiposity indices, diabetes mellitus, diabetes risk, young adults, prediction equation.

## Introduction

There is an increasing global prevalence of diabetes mellitus, a metabolic disease of the endocrine system which manifests as chronic hyperglycemia [1]. There is a significant association between obesity and diabetes [2, 3] because the former is an important modifiable risk factor associated with the latter. However, whether obesity causes diabetes mellitus is still an ongoing debate. A recent study states that obesity results from developing type 2 diabetes mellitus and not otherwise. [4]. Besides, all obese individuals do not develop type-2 diabetes mellitus [5]. Nevertheless, obesity and diabetes constitute double jeopardy for public health.

Globally, there are currently 463 million people living with diabetes mellitus and this figure is projected to reach 700 million by 2045 [6]. The global action plan aimed at halting the rise in non-communicable diseases such as diabetes by 2025 [7] and the enormous challenges in diabetes management provide logical justification for concerted efforts to prevent diabetes mellitus.

One of such strategies is the use of diabetes risk scoring models, which are inexpensive diagnostic tools for assessing diabetes risk susceptibility over a defined period [8]. Most available risk scores account for at least one adiposity index since increasing adiposity is a risk factor for diabetes mellitus. For instance, the Finnish Diabetes Risk Score (FINDRISC) utilizes two adiposity indices (body mass index (BMI) and waist circumference (WC) components) in diabetes risk scoring. FINDRISC is a simple, cheap, non-invasive and reliable diagnostic tool for identifying individuals at high risk of developing diabetes mellitus within 10 years [9]. We have recently used this tool to assess diabetes risk susceptibility in two young adult Nigerian populations [1, 8].

The need to correlate adiposity indices in young adults with diabetes risk susceptibility creates a knowledge gap. Some components of risk-scoring tools are subjective and cannot be precisely measured. This raises concerns about the accuracy and validity of scores derived from such subjective components. Since adiposity indices can be precisely measured without subjectivity, it is our considered opinion that they could serve as accurate predictors of diabetes risk. This study was designed to develop a diabetes risk score prediction equation using adiposity indices.

## Material and methods

### Participants

This study was carried out amongst young adults (aged 15–35 years) residing in Asaba, Delta State, Nigeria. A total of 200 participants (92 males; 108 females) were selected for the study by convenience sampling. After thoroughly explaining the research protocol, the intending participants, who were apparently healthy, freely signed the informed consent form prior to participation. The participants were grouped into four age groups; 15–20 years, 21–25 years, 26–30 years and 31–35 years. They were also stratified according to FINDRISC categories *viz*; <7 (low risk), 7–11 (slightly elevated risk), 12–14 (moderately elevated risk) and 15–20 (high risk).

### Exclusion criteria

Potential participants were excluded from the study based on pregnancy, drug addiction, a physical disability that impedes anthropometric measurements, and a decline of consent.

### Ethical approval and consent to participate

The study was conducted in accordance with the 1964 Declaration of Helsinki and later versions. The Delta State Ministry of Health Research Ethics Committee, Asaba, Nigeria (HM/596/T/55) approved the informed consent form, questionnaire and study protocol. Participants remained anonymous and utmost confidentiality was maintained. Only participants who read, understood and signed the informed consent form were allowed to participate in the study. A parent or legal guardian of participants under 18 years of age provided informed consent with the participants' informed assent.

### Risk scoring

The scoring of the FINDRISC tool has been described in detail in our previous paper [8]. In the FINDRISC tool, eight variable components linked with anthropometric and lifestyle patterns are scored. These components include age; BMI; waist circumference; physical activity; consumption of vegetables, fruits or berries; blood pressure medication; previous diagnosis of high blood sugar; family history of diabetes. We determined participants' total risk score as the sum of the respective scores of the different components. Participants were stratified based on their total risk score as follows: <7 (low risk); 7–11 (slightly elevated risk); 12–14 (moderately elevated risk); 15–20 (high risk).

### Anthropometric measurements

Trained research assistants did anthropometric measurements. Weight was measured (to the nearest 0.1 kg) using a weighing scale with participants dressed in light clothing and with bare feet. Height measurement (to the nearest 0.1 cm) was done using a stadiometer with the participant in an erect posture and on bare feet. Waist circumference was measured (to the nearest 0.1 cm) in a horizontal plane, midway between the lowest rib and the iliac crest, using a non-stretchable measuring tape. Hip circumference was measured (to the nearest 0.1 cm) in a horizontal plane around the pelvis at the point of maximum protrusion of the buttocks using a non-stretchable measuring tape with the participant in an erect posture. From these measurements:

Waist-to-hip ratio (WHR) was calculated as

$$WHR = \frac{Waist\ circumference\ (cm)}{Hip\ circumference\ (cm)};$$

Waist-to-height ratio (WHtR) was calculated as

$$WHtR = \frac{Waist\ circumference\ (cm)}{Height\ (cm)};$$

Body-mass-index (BMI) was calculated as

$$BMI = \frac{Weight\ (kg)}{Height\ (m)^2};$$

Body-adiposity-index (BAI) was calculated as

$$BAI = \frac{Hip\ circumference\ (cm)}{Height\ (m)^{1.5}} - 18 \ \ [10].$$

Table 1: Correlation between FINDRISC and adiposity indices.

| | | BMI | BAI | WHtR | WC | WHR |
|---|---|---|---|---|---|---|
| FINDRISC | Pearson correlation (*r*) | +0.610 | +0.561 | +0.557 | +0.495 | +0.092 |
| | Significance (2-tailed) (*p*) | (<0.001) | (<0.001) | (<0.001) | (<0.001) | (0.196) |

## Statistical analysis

Statistical analysis was done using Statistical Package for the Social Sciences (SPSS) version 23.0 (SPSS Inc Chicago IL). Pearson's linear correlation analysis, followed by a scatterplot, was used to assess the relationship between the FINDRISC score and adiposity indices at a 95% confidence level. We used multiple regression analysis to develop a prediction equation for risk score. We assessed the correlation between the predicted and calculated risk score values in the entire population using Pearson's correlation. Statistical significance was fixed at $p<0.05$.

## Results

The result of the Pearson correlation analysis shows that all the adiposity indices correlated positively with FINDRISC (Table 1). BMI had the strongest positive correlation with FINDRISC [$r$ (200)=+0.610, $p<0.001$]. We created scatter plots (Figures 1–4) to illustrate the relationship between FINDRISC and the significantly correlated adiposity indices (BMI, BAI, WHtR and WC). We excluded WHR since it was not significantly correlated to FINDRISC ($r$=+0.092; p=0.196. Taken together, these findings indicate that increases in the values of BMI, BAI, WHtR and WC significantly account for increases in FINDRISC. The effect size for BMI was deduced as $r^2$=0.372.

The result of the multiple regression analysis is presented in Table 2. From the regression analysis, we developed a prediction equation for risk score using adiposity indices, *viz*:

**Risk score=**
**-6.689+0.330(BMI)–0.059(WC)+0.078(BAI)+15.186(WHtR)**

The result of the Pearson correlation analysis in Table 3 shows that the risk score predicted with the equation had a significant positive correlation with calculated FINDRISC [$r$(200)=+0.630, $p<0.001$].

## Discussion

Obesity and diabetes are emerging public health threats with increasing prevalence corresponding to factors such as physical inactivity, unhealthy weight gain and increasing urbanization [11, 12]. This suggests that as more urban centers emerge, the burden of these

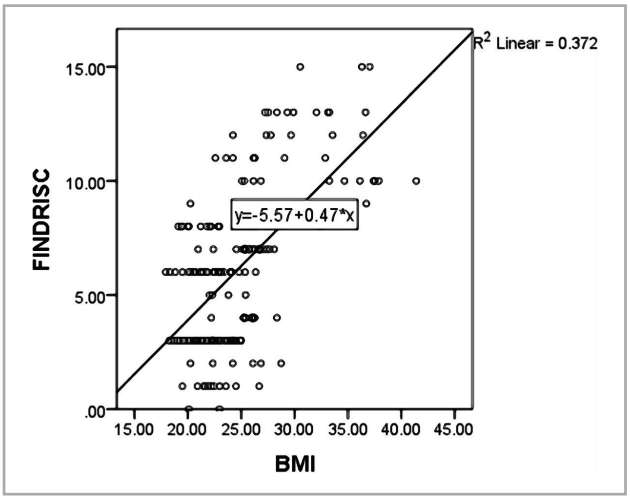


Figure 1: Scatter plot showing the correlation between BMI values and FINDRISC scores.

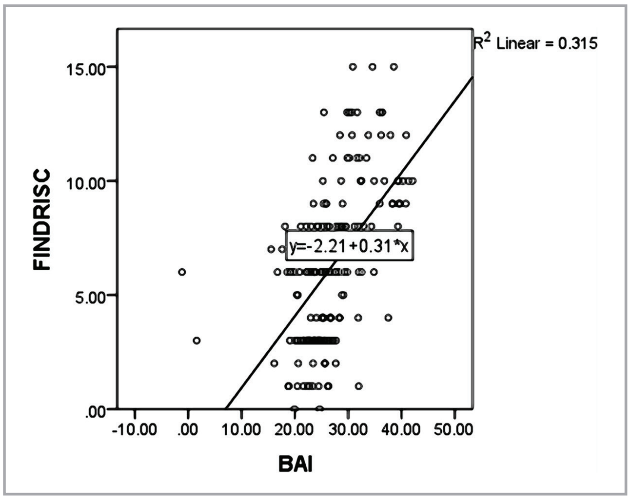


Figure 2: Scatter plot showing the correlation between BAI values and FINDRISC scores.


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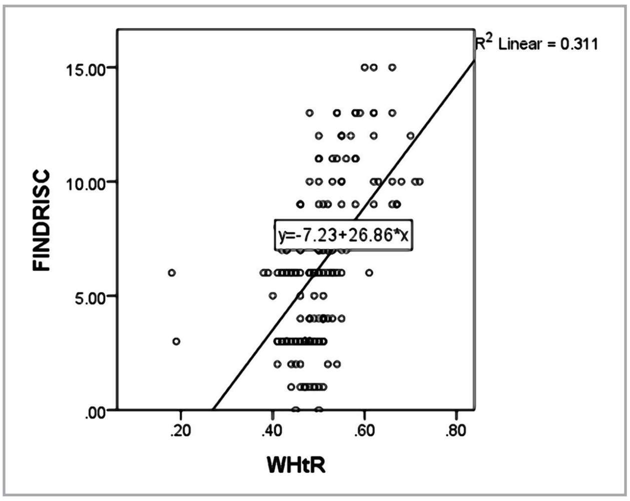


Figure 3: Scatter plot showing the correlation between WHtR values and FINDRISC scores.

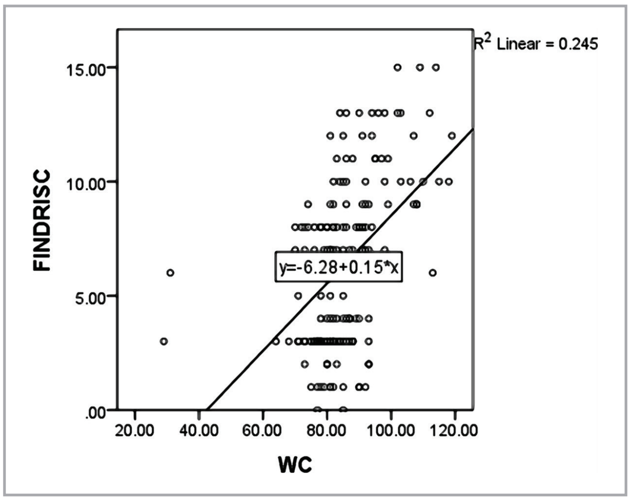


Figure 4: Scatter plot showing the correlation between WC values and FINDRISC scores.

metabolic disorders will rise. In fact, the diabetes crisis will continue even beyond this decade [13]. The global spread of obesity and diabetes is further worsened by the fact that both conditions are risk factors for the pathogenesis of non-communicable diseases, including pancreatic cancer [14].

Adiposity indices are major predisposing factors that increase the risk of cardiovascular and metabolic diseases [15, 16]. We determined the correlation of five adiposity indices with FINDRISC since they are known markers of diabetes risk [17]. BMI correlated most strongly with FINDRISC. All other indices of adiposity correlated significantly with FINDRISC except WHR. The effect size for BMI indicates that BMI values will be key determinants of risk scores.

We conducted multiple regression analysis to predict risk scores and incorporated the following adiposity indices: BMI, BAI, WC and WHtR, since these adiposity indices demonstrated statistically significant ($p<0.001$) prediction ability of risk scores. The multiple correlation coefficient, R-value of 0.644, demonstrated a good level of prediction.

The *F*-ratio value, $F$ (4, 195)=34.576, $p<0.001$, revealed that the independent variables could predict the dependent variable in a statistically significant manner. Thus, the regression model is a good fit for the data.

From the multiple regression analysis and consistent with the general form of a multiple regression equation:

$$\hat{y}=\beta_0+\beta_1x_1+\beta_2x_2+\ldots+\beta_kx_k$$

Where $\hat{y}$=predicted value of the dependent variable; $\beta_0$=the y-intercept; $\beta_1$, $\beta_2$… $\beta_k$=coefficients of the independent variables $x_1$, $x_2$…$x_k$; k=number of independent variables.

Table 2: Multiple regression analysis.

| Model | R | R square | Adjusted R square | Standard error of the estimate | F | Significance |
|---|---|---|---|---|---|---|
| 1 | 0.644 [a] | 0.415 | 0.403 | 2.664 | 34.576 | <0.001 |

Note: [a] Predictors – (Constant), WHtR, BMI, BAI, WC.

Table 3: Correlation between FINDRISC score and predicted risk score.

| | | Predicted risk score |
|---|---|---|
| **FINDRISC** | Pearson correlation (*r*) | +0.630 |
| | Significance (2-tailed) (*p*) | (<0.001) |

We developed a prediction equation for risk score using adiposity indices, *viz*:

$$\text{Risk score} = -6.689+0.330(BMI)-0.059(WC)+0.078(BAI)+15.186(WHtR)$$

From the risk score, participants' risk status can be stratified based on the FINDRISC model.

Diabetes risk scores such as FINDRISC usually involve measured and subjective variables in the questionnaire. In routine usage, objectivity is challenged as respondents often tend to under-report negative characteristics and amplify positive traits [8, 18]. This raises doubt about the accuracy of risk scores obtained from such studies.

Furthermore, some components of the FINDRISC tool, such as the level of "consumption of fruits/vegetables/berries" that meet up the daily requirement, cannot be accurately quantified by the respondents. Additionally, the lack of knowledge or denial of certain factors such as "family history of diabetes" and "use of anti-hypertensive medications" does not obliterate risk if such factors exist. Thus, the risk persists whether a respondent is ignorant of it or in denial.

Using an equation based on precisely measured adiposity indices will eliminate this uncertainty created by subjectivity. Thus, it is our considered opinion that this will give a more accurate risk status since it is determined from accurately measured indices. The positive correlation between the risk scores determined using our equation and the calculated FINDRISC scores lend credence to the usefulness of our equation. Finally, our prediction equation also has the advantage of non-invasiveness as it relies only on non-invasive parameters in predicting diabetes risk.

## Limitations and strengths

Apart from adiposity indices, other factors contribute to diabetes risk. Their exclusion due to the inability to precisely estimate them limits our study in this regard. The sampling of a specific age group rather than the entire population and the small sample size may limit our study's generalizability and statistical reliability. Considering the difficulty in participant recruitment due to the apathy usually exhibited by some young Nigerians towards health research, our modest attempt seems good enough.

The novelty of our study is a strength. Additionally, we sampled healthy young adults previously not considered for diabetes risk assessment. It is likely that other chronic complications and confounding morbidities were absent and did not compromise our results. The development of an equation from precisely measured adiposity indices will improve the accuracy of risk prediction and facilitate public health action in managing the menace of obesity and diabetes.

## Conclusion

A diabetes risk score prediction equation was developed using adiposity indices. Risk scores derived from the prediction equation had a significant positive correlation with the calculated FINDRISC. The stratification of the risk scores obtained from the prediction equation will be based on the FINDRISC model. In future studies, we recommend the utilization and validation of the developed prediction equation in diabetes risk assessment in other populations.

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## Conflict of interest

The authors declare no conflict of interest.

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## References

1. Opara BC, Ijeh II, Ejike CECC *et al*. Diabetes risk score assessment and some adiposity indices in a young adult population in Umudike, Nigeria. African J Diabetes Med 28(1): 1–7, 2020.
2. Nguyen NT, Nguyen XMT, Lane J *et al*. Relationship Between Obesity and Diabetes in a US Adult Population: Findings from the National Health and Nutrition Examination Survey, 1999–2006. Obes Surg 21: 351–355, 2011.


https://doi.org/10.46389/rjd-2022-1157

3. Haluzík M, Hrádková V, Kudláčková M *et al*. Obesity treatment in patients both with and without diabetes: current options and perspectives. Cas Lek Cesk 159(3-4): 136–140, 2020.
4. Malone JI, Hansen BC. Does obesity cause type 2 diabetes mellitus (T2DM)? Or is it the opposite? Pediatr Diabetes 20: 5–9, 2019.
5. Nagao M, Esguerra JLS, Asai A *et al*. Potential Protection Against Type 2 Diabetes in Obesity Through Lower CD36 Expression and Improved Exocytosis in β-Cells. Diabetes 69(6): 1193–1205, 2020.
6. International Diabetes Federation. Diabetes Atlas (9th edition). International Diabetes Federation, Brussels, Belgium, 2019.
7. World Health Organization. Global Action Plan for the Prevention and Control of NCDs 2013–2020. World Health Organization, Geneva, 2015.
8. Nnamudi AC, Orhue NEJ, Ijeh II. Assessment of the FINDRISC tool in predicting the risk of developing type 2 diabetes mellitus in a young adult Nigerian population. Bull Natl Res Cent 44: 186, 2020.
9. Lindström J, Tuomilehto J. The diabetes risk score: a practical tool to predict type 2 diabetes risk. Diabetes Care 26(3): 725–731, 2003.
10. Bergman RN, Stefanovski D, Buchanan TA *et al*. A Better Index of Body Adiposity. Obesity (Silver Spring) 19(5): 1083–1089, 2011.
11. Gezawa ID, Uloko AE, Gwaram BA *et al*. Pattern of Obesity Among Patients with Type 2 Diabetes at a Tertiary Healthcare Center in Northern Nigeria. Diabetes Metab Syndr Obes 12: 2785–2790, 2019.
12. Kaboré S, Millogo T, Soubeiga JK *et al*. Prevalence and risk factors for overweight and obesity: a cross-sectional countrywide study in Burkina Faso. BMJ Open 10: e032953, 2010.
13. Ampofo AG, Boateng EB. Beyond 2020: Modelling obesity and diabetes prevalence. Diabetes Res Clin Pract 167: 108362, 2020.
14. Paternoster S, Falasca M. The intricate relationship between diabetes, obesity and pancreatic cancer. Biochim Biophys Acta Rev Cancer 1873(1): 188326, 2020.
15. Bi X, Tey SL, Leong C *et al*. correlation of adiposity indices with cardiovascular disease risk factors in healthy adults of Singapore: a cross-sectional study. BMC Obes 3: 33, 2016.
16. Gomez-Marcos MA, Gomez-Sanchez L, Patino-Alonso MC *et al*. Capacity adiposity indices to identify metabolic syndrome in subjects with intermediate cardiovascular risk (MARK study). PLoS one 14(1): e0209992, 2019.
17. de Oliveira CM, Pavani J, Krieger JE *et al*. Body adiposity index in assessing the risk of type 2 diabetes mellitus development: the Baependi Heart Study. Diabetol Metab Syndr 11: 76, 2019.
18. Al-Shudifat AE, Al-Shdaifat A, Al-Abdouh AA *et al*. Diabetes Risk Score in a Young Student Population in Jordan: A Cross-Sectional Study. J Diabetes Res 2017: 8290710, 2017.