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Original Article

Measurement of visceral fat for early prediction of prediabetes—Cross-sectional study from Southern India

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الملخص

أهداف البحث: "مقدمات السكري" هي طليعة لمرض السكري من النوع 2، والفحص الروتيني لمقدمات السكري أمر بالغ الأهمية. ترتبط الدهون الحشوية بمقدمات السكري ومقاومة الأنسولين. استدعت الاختلافات العرقية التي أدت إلى مستويات مختلفة من الدهون الحشوية في السكان الهنود دراسة خاصة بالهند. هناك ندرة في الأدبيات حول القيم الفاصلة للدهون الحشوية للتنبؤ بمقدمات السكري في السكان الهنود. ومن ثم، كان الهدف الرئيس من الدراسة الحالية هو معرفة القيمة الفاصلة لدى الجنسين للدهون الحشوية للتنبؤ بمقدمات السكري في السكان الهنود.

طرق البحث: تم اختيار 300 فرد تتراوح أعمارهم بين 18 إلى 55 سنة من كلا الجنسين لهذه الدراسة المقطعية. تم تقييم الدهون الحشوية كجزء من تحليل تكوين الجسم باستخدام محلل المعاوقة الكهربائية الحيوية. تم فحص متغيرات تكوين الجسم للتنبؤ بمقدمات السكري باستخدام الانحدار اللوجستي العكسي. تم تحديد مستويات القيم الفاصلة للدهون الحشوية للتنبؤ بمقدمات السكري باستخدام تحليل "منحنى خصائص فعل المستقبلات".

النتائج: وجد أن الدهون الحشوية، والدهون الكلية، والعمر مرتبطة إحصائيا بمقدمات السكري. كما تم تحديد القيمة الفاصلة للدهون الحشوية للتنبؤ بمقدمات السكري عند الإناث على أنها 8 مع حساسية 77.8٪ وخصوصية 69.3٪. بينما في الذكور، تم تحديد 11 مع حساسية 84٪ وخصوصية 62.9٪.

الاستنتاجات: ساهمت هذه الدراسة في تحديد القيم الفاصلة بين الجنسين لمستوى الدهون الحشوية، والتي يمكن استخدامها للتنبؤ بمقدمات السكري في السكان الهنود.

الكلمات المفتاحية: السمنة؛الدهون داخل البطن؛ المعاوقة الكهربائية الحيوية؛ تكوين الجسم؛ حالة ما قبل السكري

Abstract

Objective: Prediabetes is a precursor to type 2 diabetes mellitus and routine screening of prediabetes is crucial. Visceral fat (VF) is associated with prediabetes and insulin resistance. Ethnic and racial differences resulting in different levels of VF in the Indian population necessitates an India-specific study. There is a dearth of literature on the cut-off values of VF measured using a bioelectrical impedance analyzer (BIA) to predict prediabetes in the Indian population. Hence, the main objective of this study was to determine the sex-specific cut-off value of VF on BIA to predict prediabetes in the Indian population.

Methods: Three hundred individuals aged 18–55 years of both sexes were selected for this cross-sectional study. VF was evaluated as a part of body composition analysis using BIA. The body composition variables for the prediction of prediabetes were examined using backward logistic regression. Optimal cut-off levels of VF to predict

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prediabetes were identified using receiver operator characteristic curve (ROC) analysis.

Results: VF, total fat, and age were found to be associated with prediabetes ($p \leq 0.05$). In females, the cut-off value of VF for predicting prediabetes was identified as 8 with 77.8% sensitivity and 69.3% specificity; in males, it was 11 with 84% sensitivity and 62.9% specificity.

Conclusion: This study contributes to the sex-specific cut-off values of VF level on BIA that can be used for predicting prediabetes in the Indian population.

Keywords: Bioelectric impedance; Body composition; Intra-abdominal fat; Obesity; Prediabetic state

Introduction

The global burden of type 2 diabetes mellitus (T2DM) is increasing every day.[1] Prediabetes is an intermediate stage when blood glucose levels are neither in the normal range nor are they high enough to confirm T2DM.[2] Prediabetes is a strong risk factor for T2DM. It is imperative to detect it early and prevent it from progressing to T2DM and causing further complications.[3,4] Currently, diabetes is a scourge afflicting a large portion of the Indian population, which necessitates the early prediction of prediabetes in this population. Many people might be unaware of their glycemic status, so routine screening of prediabetes is crucial.

Biochemical testing is not always possible in routine screening and epidemiological studies. As a result, risk questionnaires, anthropometric measures, and body composition measurements are becoming popular.[5–7] The role of visceral fat (VF) in prediabetes has been reported in the Caucasian population.[8,9] Prior literature on the Indian population has emphasized measures such as waist circumference (WC), sagittal abdominal diameter, and neck height ratio for the prediction of prediabetes and other metabolic risks, but these studies have not considered VF.[10–12] Measurement of WC is considered more feasible in field studies; however, in WC, we cannot differentiate VF from subcutaneous fat (SF).[13] Moreover, the prediction of metabolic risk using anthropometric measures is challenging in non-obese individuals, and any single anthropometric measure is insufficient to predict prediabetes.[14]

VF is fat around abdominal visceral organs. The unhealthy distribution of gluteofemoral fat and liver fat impacts metabolic health. Increased liver fat is closely associated with visceral adiposity, prediabetes, and T2DM.[15,16] VF can be measured using numerous techniques. Computed tomography (CT) and magnetic resonance imaging (MRI) are considered gold standard methods for the measurement of VF. Three-dimensional body scanning, ultrasonography, dual-energy X-ray absorptiometry (DEXA), anthropometric measures, and a bioelectric impedance analyzer (BIA) can also be used to measure VF indirectly.[17] BIA is a simple and convenient approach for measuring VF because it is non-invasive, cost-effective, and time-saving.[18] It also eliminates radiation exposure. BIA works on the assumption that the human body has uniform electric conductivity. Fat-free mass consists of more water and conducing electrodes than fat mass. So, conductivity is greater in fat-free mass than in fat mass.[19] In BIA, VF is predicted by measuring the impedance from some body parts. This body impedance is dependent upon the physical size, sex, and intrinsic factors such as body fat, muscles, internal organs, and water level.[20] It has been shown that BIA-assessed body fat for the prediction of prediabetes has 64% sensitivity and 59% specificity.[21]

A prior meta-analysis found significant ethnic and racial differences in the level of abdominal VF.[22] Both genetic and environmental factors are responsible for higher visceral adiposity in the Asian population compared with Caucasians.[23] Indians tend to have more VF than Caucasians and other Southeast Asians.[24] Also, in low-middle income countries such as India, where most of the population is located in rural areas, VF measurement using CT, MRI, or DEXA is a financially taxing option.

Hence, the main objective of the current study was to determine the sex-specific cut-off value of VF on BIA to predict prediabetes in the Indian population.

Materials and Methods

Study design

This cross-sectional study was conducted and reported as per the Strengthening the Reporting of Observational studies in Epidemiology (STROBE) guidelines.

Setting

The study was conducted in Southern India from January 2020 to March 2021. Data collection was done following approval from the institutional research committee and institutional ethics committee. For sample recruitment, a convenience sampling method was used. Samples were recruited from community screening, as well as the medical outpatient department of a tertiary care center located in South India. Voluntary participants were included after providing written informed consent. The Dravidian race composes the majority of South India's population.[25,26] This study included participants from south India to ensure that the sample was composed of people of the same race and ethnicity.

Participants

Three hundred individuals of both sexes aged 18–55 years were selected for this study. The exclusion criteria were: individuals with known type 1 or type 2 diabetes or those on medication to control blood sugar levels; individuals with chronic neurological, cardiovascular, or musculoskeletal impairment that restricts physical activity; pregnant women; and individuals with chronic kidney disease, a pacemaker, or metallic implants in the body.

Variables

The primary outcome variables of this study were prediabetes and VF level.

Prediabetes

The values of glycemic parameters used to validate the diagnosis of prediabetes were according to the American Diabetes Association (ADA) guidelines.[27] The individuals were in the prediabetes category when the fasting blood sugar (FBS) was between 100 and 125 mg/dL (5.6–6.9 mmol/L) and glycated hemoglobin (HbA1C) was between 5.7% and 6.4%.

VF

In this study, VF was measured as a part of body composition analysis. We used BIA to measure body composition. The estimation of VF using the BIA instrument was based on an inbuilt equation.[20] Other body composition variables included weight, body mass index (BMI), total fat (TF) (%), SF (%), skeletal muscle mass (SMM) (%), and VF level.

Hypotheses

This study evaluated the following hypotheses.

Null: VF is not associated with prediabetes in the Indian population.

Alternative: VF is positively associated with prediabetes in the Indian population.

Data sources and variables measurement

The participants' demographic information including age, sex, height, and WC was recorded before checking their glycemic parameters and body composition. Height was recorded in centimeters using either a wall-mounted stadiometer or non-stretchable inch tape. WC was recorded using non-stretchable inch tape at the umbilicus level. The level of physical activity, family history of T2DM, and history of gestational DM was noted.

Glycemic parameters

Glycemic parameters used for the diagnosis of prediabetes were FBS and HbA1C. FBS was measured after a minimum of 10–12 h of overnight fasting from venous blood. HbA1C level calculated in the previous 3 months was deemed sufficient to confirm the diagnosis of prediabetes.[28]

Body composition measurement

Body composition measurement included weight, BMI, TF, SF, SMM, and VF. Body composition was evaluated using the Omron Karada Scan Body Composition & Scale (HBF-701). It consists of eight-contact electrodes at an anatomical landmark, namely both footpads and handles. BIA analyzers introduce a small electrical current into the body and measure the impedance to current flow. The Omron Karada Scan uses an electrical current of 50 kHz, 500 μA. Participants refrained from consuming food, tea, coffee, alcohol, and smoking. They were also restricted from performing strenuous physical activities for at least 2 h before the body composition examination.[29] Participants wore loose and comfortable clothing that did not consist of metallic or electronic items. The hands and feet of each participant were clean and dry before handling the instrument. Measurement was taken from the person's standing position, with their arm at a 90° angle with the body.

Bias

To avoid measurement bias, the same investigator evaluated the body composition of all participants.

Study size

Sample size was calculated by using the formula, $n = (Z_{1-\alpha/2})^2\ P(1-P)/d,^2$ considering P = 14% prevalence and d = 4% precision.[30,31] The minimum required sample size for the study was 290 participants.

Quantitative variables

Quantitative variables of demographic information, glycemic parameters, and body composition variables were analyzed using descriptive statistics to determine the mean and standard deviation.

Statistical analysis

Statistical analysis was performed using SPSS 20 statistical software. The independent *t*-test was performed to identify the differences in descriptive values in males and females, as previous studies have also reported the influence of sex on lean and fat mass.[32] Backward stepwise linear regression was performed to examine the association of body composition variables with each of the two prediabetes parameters (i.e., FBS and HbA1C). Furthermore, backward logistic regression was performed to investigate the body composition variables for the prediction of prediabetes. Receiver operator characteristic curve (ROC) and area under the curve (AUC) were used to identify the optimal cut-off levels of VF to predict prediabetes.

Results

Demographics

This study enrolled 300 participants, including 197 females and 103 males aged 18–55 years. Table 1 summarizes the demographic information, glycemic parameters, and body composition variables of the participants. Age, BMI, FBS, and HbA1C did not vary between both sexes, but a significant difference was found in weight, WC, TF, SF, SMM, and VF levels between males and females ($p \leq 0.05$).

Association of body composition variables with FBS and HbA1C

Before running the regression, the variable 'TF to SMM ratio' was prepared to nullify the correlation effect between TF and SMM. Variables included in the analysis were age, sex, TF VF, SF, SMM, TFSMM. VF and age found associated with FBS. Whereas, VF, TF/SMM, and age was associated with HbA1C. We found that a single unit change in VF increased the value of FBS by 0.26 units and of HbA1C by 0.35 units (Table 2A, B).

Table 1: Demographic information, glycemic parameters, and body composition variables of participants.

Parameter	n = 300 F = 197 M = 103	Mean ± SD	*p*-value
Age (years)	M	40.7 ± 10.4	0.434
	F	41.7 ± 10.4	
FBS (mg/dL)	M	101.5 ± 15.3	0.749
	F	100.7 ± 20.8	
HbA1C (%)	M	5.5 ± 0.3	0.517
	F	5.5 ± 0.5	
Weight (kg)	M	72.5 ± 15.3	≤0.001
	F	61.07 ± 12.5	
WC (cm)	M	92.6 ± 10.5	≤0.001
	F	88.1 ± 10.2	
BMI (kg/m^2)	M	25.9 ± 4.8	0.241
	F	25.2 ± 4.8	
TF (%)	M	27.3 ± 5.9	≤0.001
	F	35.3 ± 5.2	
VF	M	11.7 ± 6	≤0.001
	F	7.8 ± 5	
SF (%)	M	19.0 ± 4.4	≤0.001
	F	30.0 ± 6	
SMM (%)	M	29.7 ± 2.8	≤0.001
	F	23.2 ± 2.3	

WC: waist circumference, FBS: fasting blood sugar, BMI: body mass index, TF: total fat, VF: visceral fat, SF: subcutaneous fat, SMM: skeletal muscle mass, F: females, M: males.

Table 3: Body composition variables for prediction of prediabetes.[a]

Variable	B	SE	*p*-value	Exp (B)	95% CI for Exp (B)	
					Lower	Upper
TF	0.21	0.09	0.016	1.24	1.04	1.47
VF	0.18	0.04	≤0.001	1.19	1.10	1.30
Age	0.13	0.02	≤0.001	1.14	1.09	1.18

VF: visceral fat, TF: total fat.
[a] Diagnosed based on levels of FBS and HbA1C.

Body composition variables for the prediction of prediabetes

Diagnosis of prediabetes is a function of the level of FBS and HbA1C as per the ADA.[27] Thus, it is essential to assess the impact of body composition variables on the diagnosis of prediabetes. The sample was split into those diagnosed with prediabetes (n = 93) and those with normal glycemic levels (n = 207). Backward logistic regression was run to determine the impact of age, sex, VF, TF, SF, SMM, and TF/SMM on the diagnosis of prediabetes. TF, VF, and age were found to be associated with prediabetes (Table 3).

Table 4: Diagnostic accuracy of visceral fat for the prediction of prediabetes.

Characteristics	AUC	SE	95% CI	Optimal Cut-off	Sensitivity (%)	Specificity (%)
VF (F)	0.78	0.03	0.71–0.84	>7.75	77.8	69.3
VF (M)	0.82	0.04	0.73–0.91	>0.75	84.8	62.9

VF: visceral fat, AUC: area under curve, M: males, F: females.

Table 2: Association of body composition variables with FBS and HbA1C.

Variables	Unstandardized coefficient		Standardized coefficient	t	*p*-value	95% CI	
	B	SE	Beta			Lower	Upper
A. Dependent variable FBS							
VF	0.83	0.18	0.26	4.39	≤0.001	0.45	1.20
Age	0.63	0.11	0.34	5.69	≤0.001	0.41	0.84
B. Dependent variable HbA1C							
VF	0.03	0.00	0.35	5.70	≤0.001	0.02	0.04
TF/SMM	0.17	0.07	0.15	2.35	0.020	0.02	0.33
Age	0.01	0.00	0.31	5.08	≤0.001	0.01	0.02

FBS: fasting blood sugar, HbA1C: glycated hemoglobin, TF: total fat, VF: visceral fat, SMM: skeletal muscle mass.

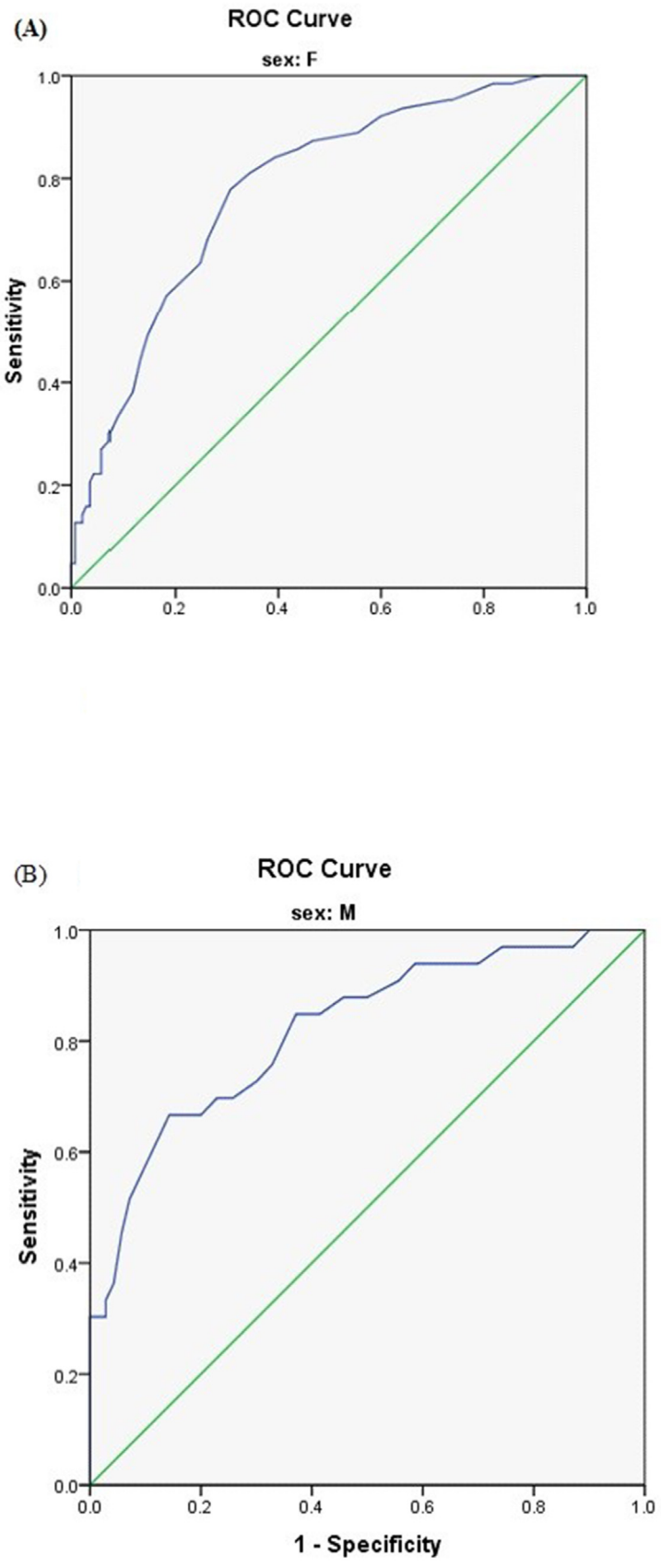

Figure 1: ROC curve of visceral fat in (A) females and (B) males as a predictor of prediabetes.

Diagnostic accuracy of VF for the prediction of prediabetes

Table 1 clearly shows the significant difference in average VF levels between males and females. Hence, we conducted ROC analysis separately for both sexes. In females, the cut-off value of VF for the prediction of prediabetes in females was 8 with 77.8% sensitivity and 69.3% specificity; in males, the cut-off value of VF was 11 with 84% sensitivity and 62.9% specificity (Table 4 and Figure 1A, B).

Discussion

This cross-sectional study determined the sex-specific cut-off value of VF on BIA to predict prediabetes in the Indian population. Three hundred participants of both sexes aged 18−55 years were selected to evaluate glycemic parameters and body composition variables. The results showed that VF was a significant predictor of prediabetes. In addition, the cut-off value of VF on BIA was found to be 8 in females and 11 in males to predict prediabetes in the Indian population.

VF as a predictor of prediabetes and the role of SMM

In regression analysis, the VF was a significant measure to predict prediabetes (Tables 2 and 3). This supports the alternative hypothesis and our null hypothesis was rejected. These findings are consistent with a previous study on the Korean population, which reported that VF was strongly associated with diabetes and prediabetes.[33] A study on the Iranian population showed that individuals with prediabetes had higher VF.[34] The anatomical location of VF plays a unique role. Adipokines and cytokines released from VF drain into the portal vein and so the liver is exposed to undiluted secretions from VF. Increased VF increases the release of free fatty acid, which is responsible for the decrease in insulin sensitivity and reduction in peripheral glucose uptake.[35] This causes an increase in blood glucose levels, which leads to the development of prediabetes that can progress to diabetes if left untreated. VF consists of higher macrophage infiltration that promotes a pro-inflammatory profile and subsequently insulin resistance.[36]

In backward stepwise linear regression, this study determined that the TF to SMM ratio was associated with HbA1C values (Table 2B). Skeletal muscles are the hallmark of metabolic syndrome, as they are the critical site of peripheral glucose uptake.[37] Reduction in muscle mass increases insulin resistance and results in elevated blood sugar levels that eventually turn into prediabetes and later into T2DM. The SMM to VF ratio is an essential determinant of T2DM and metabolic syndrome.[38]

Sex-specific cut-off value of VF to predict prediabetes in the Indian population

According to this study, the cut-off value of VF to predict prediabetes among females and males was 11 8, respectively, on BIA (Table 4 and Figure 1). This sexual dimorphism in body fat distribution is due to the influence of sex hormones.[39] Females tend to have more subcutaneous adipose tissue, whereas males tend to have more visceral adipose tissue.[39] Females can effectively store the fatty acid in subcutaneous adipose tissue,[40] which results in more SF in females compared to males.[41] Whereas males store the fatty acid in visceral adipose tissue, which results in more VF depots. This might be the reason that females have lower VF than males. The results of this study showed a significant association between age and prediabetes. Aging is one more factor associated with the level of VF. With increasing age, there is a reduction in sex hormones that causes an increase in the level of VF.

Table 1 shows that the average TF and SF were higher in females, whereas VF was higher in males. Typically, women have approximately 10% higher body fat than men throughout their lifespan. Pregnancy as well as postpartum causes more fat deposition in females. During puberty, females accumulate more fat mass whereas males accumulate more muscle mass.[42] That might be the reason for the higher TF in females in this study. Visceral adiposity increases in females in the perimenopause stage due to a reduction in estrogen.[43]

A study on the Japanese population reported 10 as a VF level cut-off value for screening metabolic syndrome.[44] Variation in cut-off value is due to ethnic and racial differences in the level of abdominal VF.[22] East Asians have less body fat than South and Southeast Asians.[23] The 'thin-fat' phenotype was observed in Indian neonates, confirming the truncal adiposity at the time of birth.[24]

BIA underestimates the reading of VF than that measured with CT; nonetheless, the error of estimation is less than the acceptable range.[45] VF measured by BIA shows a close correlation with that of CT, MRI, and DEXA.[46–49] The correlation between BIA and CT was better than that of BMI and WC.[47] Hence, it is strongly recommended for routine clinical screening.

This study focused on identifying separate cut-off values of VF for males and females in the Indian population for the prediction of prediabetes. The results of this study will be valuable for screening for prediabetes in routine clinical practice. The small sample size was one of the major limitations of this study. The second limitation was the lack of data on the dietary patterns of the participants, as dietary pattern has an impact on VF.[50] The third limitation was a lack of consideration of oral glucose tolerance test (OGTT) value. As per the ADA, prediabetes diagnosis can be confirmed based on FBS, OGTT, and HbA1C.[27] Of the three recommended criteria, FBS and HbA1C were considered in this study. Future studies with a higher sample size and considering different dietary patterns should be performed to reconfirm the results.

Conclusion

This study contributes to the sex-specific cut-off values of VF level on BIA that can be used for the prediction of prediabetes in the Indian population. This study identified the cut-off value of VF as 8 in females and 11 in males to predict prediabetes in the Indian population. We recommend the measurement of VF in routine clinical practice for screening prediabetes.

Abbreviations: ADA, American Diabetes Association; T2DM, type 2 diabetes mellitus; FBS, fasting blood sugar; HbA1C, glycated hemoglobin; OGTT, oral glucose tolerance test; WC, waist circumference; BMI, body mass index; TF, total body fat; SF, subcutaneous fat; VF, visceral fat; SMM, skeletal muscle mass; BIA, bioelectrical impedance analyzer; ROC, receivers operating characteristic; AUC, Area under the curve.

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Conflict of interest

The authors have no conflict of interest to declare.

Ethical approval

Ethical approval was provided by Kasturba Medical College and Kasturba Hospital Institutional Ethics Committee (Reference No. 867/2019) on December 11, 2019.

Consent

Voluntary participants were included after providing written informed consent for study participation.

Authors contributions

RJ: Conceptualization, data curation, analysis, manuscript writing. GAM: Conceptualization, methodology, critical review. SKN: Data curation, supervision, critical review. SU: Data curation, supervision, analysis. All authors have critically reviewed and approved the final draft and are responsible for the content and similarity index of the manuscript.

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