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Original Research

Correlation between Bioelectric Impedance Analysis-Measured Body Fat, Body Mass Index and Waist Circumference with Cardiovascular Risk Factors in Acute Coronary Syndrome Patients

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ABSTRACT

Estimation of fat using bioelectrical impedance analysis (BIA) is thought to be a more predictive measure of cardiovascular (CV) risk assessment than body mass index (BMI) or waist circumference (WC). Percent body fat as measured using BIA (BIA-BF%) is independently associated with future cardiovascular events namely acute myocardial infarction, ischemic heart disease. This study is conducted to determine the correlation between body fat which consists of BIA-BF%, percentage of subcutaneous adipose tissue (SAT) and visceral fat level (Visceral Adipose Tissue/VAT) measured using BIA device, BMI and WC with CV risk factors (blood pressure, blood glucose level, LDL, HDL, TG, total cholesterol, HbA1c and serum fibrinogen) in patients with acute coronary syndrome (ACS). **Material and Methods :** This study used a cross-sectional correlation analysis. Sample was 70 ACS patients that match with inclusion criteria. **Results :** We found significant correlations between BIA-BF% with diastolic blood pressure, TG, and total cholesterol ($r = 0.246$, $r = 0.250$, $r = 0.348$ respectively; $p < 0.05$). There was a significant correlation between VAT with diastolic blood pressure, LDL, TG, total cholesterol, HbA1c, and fibrinogen ($r = 0.299$, $r = 0.306$, $r = 0.278$, $r = 0.265$, $r = 0.292$, $r = 0.330$ respectively, $p < 0.05$). There was a significant correlation between the percentage SAT and HDL levels ($r = 0.318$; $p < 0.05$). We found no correlation between BMI and WC with blood pressure, LDL, HDL, TG, blood glucose, HbA1c and fibrinogen levels in ACS patients. **Conclusion:** VAT and BIA-BF% correlate with several cardiovascular risk factors better than BMI and WC. Body fat examination using BIA may be done to manage risk factors in ACS patients.

Introduction

Acute coronary syndrome (ACS) occurs because of various cardiovascular risk factors [1]. These various risk factors can be affected by body fat [2]. In a meta-analysis, it is found that the risk of coronary heart disease (CHD) is increased by 5% per 1 kg/m^2 increase in body mass index (BMI), 22% in overweight subjects and 61% in obese individuals. [4]

The INTERHEART study found a strong positive correlation between waist circumference and the risk of myocardial infarction, indicating that central obesity has an effect on the risk of myocardial infarction. The effects of body fat, especially abdominal fat, on the risk of cardiovascular disease are mostly mediated through other risk factors, namely hypertension, the tendency to develop

diabetes mellitus, increased blood coagulability and changes in blood lipid profiles [5]. Visceral fat is thought to be more harmful than subcutaneous fat, however the amount of visceral and subcutaneous fat is highly correlated [5,6]. Body fat can be measured using CT scan and MRI, but they are costly, requiring experts and they bring about radiation exposure [5,7]. Bioelectrical impedance analysis (BIA) is a noninvasive, inexpensive, easy and beneficial tool in the clinical evaluation of body fat [8,9]. Almost all primary health care facilities in Indonesia own this tool but they are underused. [10]

The principle underlying this method is that lean body mass conducts a certain voltage more efficiently than fat mass [8,11]. In the PREVEND cohort study, the estimation of fat by BIA-BF% could be a more predictive measure of cardiovascular risk assessment than BMI or waist circumference. BIA-BF% is independently associated with future cardiovascular events namely acute myocardial infarction, coronary artery bypass action or percutaneous transluminal coronary angioplasty, and ischemic heart disease. [12]

However, until now, the relationship between body fat using BIA and cardiovascular risk factors in ACS patients has not been studied and given less attention [3]. This study was conducted to determine the connection between body fat which consists of total body fat percentage(BF%), subcutaneous adipose tissue (SAT) and visceral adipose tissue level (/VAT) measured using the BIA device, body mass index (BMI) and waist circumference (WC) with cardiovascular risk factors consisting of blood pressure, blood sugar, LDL, HDL, TG, total cholesterol, HbA1c and serum fibrinogen level in ACS patients at Dr. Soetomo General Hospital Surabaya.

Material and Methods

This is an observational study with a cross sectional design, conducted at Dr. Soetomo General Hospital Surabaya during March 2019 - April 2020. The samples enrolled in the study were 70 participants aged over 18 years with acute coronary syndrome (ACS) that signed the informed consent. Exclusion criteria were ACS patients accompanied by heart failure functional class III-IV, signs of shock, dehydration, amputated limb, not being able to maintain body balance, on routine hypertensive drugs, and on routine anti-hyperlipidemia drugs.

Drop out criterion was patients resigning from the study. This study was using purposive sampling method with minimal sample size of 70 (calculated by correlation coefficient formula). All samples underwent history taking, physical examination, and diagnostic procedures to diagnose ACS. ACS consists of three types, namely ST elevation myocardial infarction (STEMI), non-ST elevation myocardial infarction (NSTEMI) and unstable angina (UA). The diagnostic definition of ACS is based on the integration of symptoms, electrocardiography (ECG) and cardiac troponin enzymes. [2,13]

These patients underwent procedures to measure BIA-BF%, VAT, SAT, BMI, and WC (5 independent variables), as well as blood sample analysis (blood samples drawn after 8-12 hours of fasting) for LDL, TG, HDL, total cholesterol, fibrinogen, random blood glucose, HbA1c serum, and blood pressure measurement (9 dependent variables). Blood tests are carried out according to the operational standards of blood collection and blood biochemical tests.

All data obtained data were processed using SPSS 23 software then analyzed bivariate analysis using the Pearson correlation test, which the normality of the data previously confirmed using the Kolmogorov-Smirnov test. If the data were not normally distributed, it would be processed using the Spearman correlation test. The level of significance used was 95%. The ethical feasibility of this research was gained from the ethics committee of Dr. Soetomo General Hospital Surabaya. The patient participation consent statement was stated in the form of signing the informed consent by the patient and family.

Result

In this study, from 70 subjects, 75.7% of them were male with baseline characteristic of all subjects listed in Table 1 and parameters measured in this study listed in Table 2.

Table 1. Baseline characteristics. ACS = acute coronary syndrome.

Variables	Minimum	Maximum	Mean	SD
Age	32	82	56.21	9.707
Systolic BP	85	180	126.56	21.741
Diastolic BP	40	100	76.67	12.565
Blood glucose	76	552	208.83	131.690
Total cholesterol	92	301	185.94	51.896
LDL	50	194	118.04	39.222
HDL	19	234	50.27	30.892
TG	50	401	158.80	64.936
HbA1c	5.4	12.5	7.296	1.8191
Fibrinogen	139.3	820.8	420.464	153.1590
BMI	16.2	35.8	25.137	4.0169
Waist circumference	69	125	98.69	11.179
Body Fat (%)	11.8	45.3	29.180	6.9789
SAT (%)	8.8	39.6	21.057	6.7036
VAT	2.0	22.5	11.516	4.6774
Skeletal muscle (%)	18.2	38.2	27.323	4.1305

Table 2. Parameters measured in all subjects. BP = blood pressure, LDL = low density lipoprotein, HDL = high density lipoprotein, TG = triglyceride, BMI = body mass index, SAT = subcutaneous adipose tissue, VAT = visceral adipose tissue

Characteristic		Frequency	Percentage (%)
Sex	Male	53	75.7
	Female	17	24.3
ACS	NSTEMI	11	15.7
	Recent MI	6	8.6
	STEMI	49	70.0
	UA	4	5.7
Smoking	Yes	47	67.1
	No	23	32.9
History of diabetes mellitus	Yes	27	38.6
	No	43	61.4
History of hypertension	Yes	22	31.4
	No	48	68.6

Table 3. Correlation between BIA-BF%, VAT, SAT, WC, and BMI with blood pressure. BP = blood pressure, BIA-BF% = percentage of bioelectrical impedance analysis – body fat, SAT = subcutaneous adipose tissue, VAT = visceral adipose tissue, WC = waist circumference, BMI = body mass index

Variables	Systolic BP		Diastolic BP	
	r	p	r	p
BIA-BF%	0.199	0.098	**0.246**	**0.040**
SAT	0.206	0.087	0.174	0.150
VAT	0.121	0.320	**0.299**	**0.012**
WC	0.074	0.541	0.169	0.161
BMI	0.107	0.380	0.158	0.192

Table 4. Correlation between BIA-BF%, VAT, SAT, WC, and BMI with lipid profile. BIA-BF% = percentage of bioelectrical impedance analysis – body fat, SAT = subcutaneous adipose tissue, VAT = visceral adipose tissue, WC = waist circumference, BMI = body mass index, LDL = low density lipoprotein, HDL = high density lipoprotein, TG = triglyceride.

Variables	LDL		HDL		TG		Total cholesterol	
	r	p	r	p	r	p	r	p
BIA-BF%	0.196	0.104	0.198	0.100	**0.250**	**0.037**	**0.348**	**0.003**
VAT	**0.306**	**0.010**	0.090	0.459	**0.278**	**0.020**	**0.265**	**0.026**
SAT	0.067	0.581	**0.318**	**0.007**	0.050	0.679	0.153	0.207
WC	-0.024	0.843	0.068	0.578	-0.022	0.858	-0.020	0.869
BMI	-0.043	0.724	0.051	0.673	-0.610	0.614	-0.160	0.894

Table 5. Correlation between BIA-BF%, VAT, SAT, WC, and BMI with blood glucose, HbA1c, and fibrinogen levels. BIA-BF% = percentage of bioelectrical impedance analysis – body fat, SAT = subcutaneous adipose tissue, VAT = visceral adipose tissue, WC = waist circumference, BMI = body mass index.

Variables	Blood glucose		HbA1c		Fibrinogen	
	r	p	r	p	r	p
BIA-BF%	0.064	0.596	0.136	0.261	0.019	0.879
VAT	0.120	0.323	**0.292**	**0.014**	**0.330**	**0.005**
SAT	0.018	0.884	0.119	0.326	0.064	0.597
WC	-0.045	0.714	0.078	0.522	0.074	0.541
BMI	-0.028	0.820	0.080	0.509	0.016	0.897

Discussion

Obesity increases a number of risk factors for cardiovascular disease, however some types of patients with cardiovascular disease may have a better prognosis if they are overweight or obese, called “obesity paradox” phenomenon [14]. However, a study by Kadakia et al. showed that the group with the lowest BMI and highest waist circumference had the highest risk of cardiovascular death in post-NSTEMI patients. Obesity is associated with more favorable short-term outcomes after ACS. However, in the long term the paradox of the obesity no longer exists and can have the opposite effect. Patients with disproportionate waist circumference and BMI, which indicates significant central obesity, may have the highest risk after ACS. [15]

In this study, an examination of the variable body fat profile in ACS patients using bioelectrical impedance analysis (BIA). The body fat parameters measured were total body fat percentage (BIA-BF%), visceral fat level (VAT), subcutaneous fat percentage (SAT), body mass index (BMI) and waist circumference. BIA examination is a cheap, non-invasive and non-radiation method in analyzing body fat profiles. Almost all of primary health facilities in Indonesia have this device as the program from health ministry.

In this study, a significant correlation was found between BIA-BF% and VAT with diastolic blood pressure. The results of this study are consistent with a study conducted by Lee et al. that showed parameters of BMI, waist circumference and percentage of body fat (PBF) was consistently associated with an increased likelihood of hypertension prevalence. Even in individuals with normal BMI, the likelihood of the prevalence of hypertension was consistently increased in those with central obesity and those with high PBF [14]. Body fat percentage in Lee et al. study was measured using the dual-energy X-ray absorptiometry (DXA) method. In addition, a cross-sectional study by Xue et al found that a higher visceral adipose index (VAI) score was associated with higher blood pressure levels and a higher risk of hypertension [17]. Percentage of body fat in Lee et al. study was measured by whether visceral fat in the Xue et al., study was calculated using VAI score.

In this study, a significant correlation was found between the percentage of body fat (BIA-BF%) with TG, as well as, between visceral fat scale (VAT) with LDL, TG, and total cholesterol. The results of this study are in line with a cross-sectional study by Y. C. Lee et al. that determining the usefulness of

the BIA tool in predicting metabolic syndrome. Multiple regression analysis in Y. C. Lee et al. study showed that TG, SBP, and DBP levels increased while HDL decreased with increasing levels of visceral fat (VAT) in both sexes. In our study, we found a significant relationship between VAT and LDL, whereas in the study of Y. C. Lee et al., such result was not found [21]. The level of visceral fat (VAT) and body fat percentage (BIA-BF%) in the YC Lee et al. study was measured using Body Composition Analyzer TANITA AB 140Viscan BIA device while in this study, the one used was the Body Fat Monitor Omron HBF-375 device. In this study, it was also found that there's a significant correlation between the percentage of superficial fat (SAT) and HDL levels. These results are consistent with a study by Rønn et al. from three studies in Greenland, Kenya and Denmark. who found that higher SAT was associated with higher HDL-C in African men and was associated with lower HDL-C in men of Inuit race. An increase in VAT by one standard deviation was associated with an increase in hepatic insulin resistance and an increase in TG which was independent of BMI [22].

In this study, a significant correlation was found between the visceral fat scale (VAT) with HbA1c and fibrinogen levels. The results of this study are consistent with a cross-sectional study by Zhang et al. which showed that higher areas of visceral fat and areas of subcutaneous fat were associated with fasting blood sugar, 2-hour post prandial blood sugar, HbA1c and disposition index (DI) after adjusting for other covariates. However, the strength of the relationship between visceral fat area those parameters was weaker than waist hip ratio (WHR) and waist circumference, but slightly stronger than BMI. Usui et al. [23] also found that when compared to the group with low visceral fat, the group with high visceral fat had a higher prevalence of pre-Diabetes Mellitus or Diabetes Mellitus diagnosed by high HbA1c [24]. In a study by Wu et al., it was found that the plasma concentrations of Fibrinogen like protein 1 (FGL1) was significantly higher in the obese group than in the normal weight group, and was positively correlated with age, BMI, waist circumference, fat content, plasma glucose at 2 hours during oral glucose tolerance test, and index insulin sensitivity. [25]

VAT produces many biologically active molecules including adipokines (e.g., leptin, adiponectin, and omentin), cytokines/chemokines (e.g. IL-6, TNF-α +, monocyte chemoattractant protein-1 [MCP-1]), gas molecules (e.g., nitric oxide [NO], and hydrogen sulfide [H_2S]), prostacyclin, angiotensin-1 to 7 (Ang 1–7), Ang II, methyl palmitate and reactive oxygen species (ROS). All of these molecules contribute to vascular homeostasis. Adiponectin, NO, H_2S, prostacyclin, Ang 1-7 and methyl palmitate induce vasodilation by targeting the underlying EC and VSMC in the vessel wall. Ang II, ROS and other undetermined factors cause vasoconstriction. secretes more inflammatory adipokines/cytokines, including TNF-α, leptin, IL-6, plasminogen activator, and resistance, which in turn can alter the characteristics and secretions of PAT, ultimately affecting vascular homeostasis. [18-20]

Visceral adiposity is the main source of free fatty acids (FFA) which will be released to the liver (through the splanchnic circulation) and then into the circulatory system. The dysfunctional adipose tissue that is associated with the VAT results in increased plasma FFA levels and flow, which in turn leads to ectopic lipid deposition and lipotoxicity. The liver response to high levels of FFA, chylomicrons, postprandial lipoproteins and dietary cholesterol results in insulin resistance in the liver and local lipid accumulation mediated by dysregulation of hepatic glucose production and increased liver de novo lipogenesis. Intramyocellular lipid

accumulation (IMLA) is a possible precursor to local insulin resistance, because the increased absorption of fatty acids is associated with chronic lipid excess and beta-oxidation disorders. In addition, there is strong evidence that increased plasma FFA induces resistance to insulin through inhibition of glucose transport and/or phosphorylation with subsequent reductions in the rate of glucose oxidation and muscle glycogen synthesis. PAI-1 is a highly responsive/induced adipokine by pro-inflammatory cytokines and reactive oxygen species (ROS), particularly cytokines associated with VAT and hepatic ectopic fats such as TNF-α, altering growth factor (TGF-β) and insulin. The high reactivity of PAI-1 and fibrinogen to proinflammatory cytokines, such as CRP and IL-6, also suggests an association between this proinflammatory and prothrombotic state in the pathophysiology of MetS. Thrombotic etiology goes through chronic inflammation and fibrinolytic disorders, which can trigger endothelial dysfunction, plaque rupture with tissue exposure factors, platelet activation, and advanced blood clot fragmentation.

Regarding atherogenic events, dyslipidemia is one of the pillars of a cardiometabolic multi-faceted etiology. TG production is associated with high FFA availability. In a positive feedback cascade, both disruption in insulin signaling and increased FFA stimulate VLDL modulation production, apoB metabolism and lipoprotein lipase (LpL). Increased IR leads to deficiency of lipoprotein lipase, the enzyme responsible for low fasting and postprandial triglyceride-rich lipoprotein (TRL) clearance, and decreased production of HDL. [26]

The results of this study indicate that in ACS patients, body fat is correlated with various other cardiovascular risk factors. ACS is one of the main diseases in the field of cardiology with the highest risk of morbidity and mortality (Piepoli et al., 2016). The higher a person's risk the greater the benefits of managing risk (Jennings, Graham and Gielen, 2016). The results of this study show much in common with the results of recent studies measuring the correlation between body fat percentage, VAT and SAT and cardiovascular risk factors measured using CT scan, MRI, DXA, equation formulas and BIA modalities. BIA has sensitivity and specificity that is not much different from the various modalities of measuring body fat based on radioactive or not. The wide availability of BIA, affordable price and fast and easy operation are the supporting capacities for optimizing the use of this device in the management of cardiovascular risk factors in ACS patients. In addition, VAT parameters and body fat percentage from BIA measurements have a better correlation with conventional risk factors when compared to body mass index and waist circumference (D. Hart, 2019).

Cardiologists should pay attention to body fat percentage, VAT and SAT measured using BIA in ACS patients, in order to carry out a comprehensive cardiovascular risk factor analysis because being overweight can be a cause of the cardiovascular disease, because it can be associated with a higher level of conventional risk factors (Piepoli et al., 2016). So far, the management of risk factors for ACS patients uses antiplatelet therapy, beta blockers, statins, ace-inhibitors (class I, LOE A) and mineralocorticoids (class I, LOE B) (Ibanez et al., 2017). Managing VAT and body fat of ACS patients will support the successful use of antihypertensive, antidiabetic, antilipidemic, antiplatelet in the management of hypertension, LDL, TG, total cholesterol, HbA1c and fibrinogen in ACS patients. Although specifically, further research is still needed.

The number of samples in this study is quite small, therefore generalization of the result needs further study with larger samples. BIA examination and blood sampling were not done at the same moment and no screening of nutritional and hydration status were conducted before BIA examination.

Conclusion

We found a correlation between BIA-BF% with diastolic blood pressure, total cholesterol, and TG levels; correlation between VAT with diastolic blood pressure, LDL, TG, total cholesterol, fibrinogen, and HbA1c levels; correlation between SAT with HDL level on ACS subjects. VAT and BIA-BF% have correlation with several cardiovascular risk factors better than BMI and WC on ACS subjects, therefore, body fat examination using BIA may be utilized to manage risk factors in ACS patients.

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