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Is fat-to-lean mass ratio a better predictor of heart variability than body mass index?

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Abstract:

BACKGROUND: Body mass index (BMI) may not accurately predict cardiometabolic risk due to confounders like age, gender, relatively high lean mass, and the "thin-fat phenotype" prevalent in south Asian populations. Fat-to-lean mass ratio (FTLM), which assesses the balance between fat and lean body mass, may provide a more complete assessment of cardiometabolic health.

MATERIALS AND METHODS: This cross-sectional analytical study investigated the relationship between FTLM ratio, BMI, and heart rate variability (HRV) in apparently healthy male adults. 88 participants recruited through convenience sampling underwent anthropometric assessments, bioimpedance body composition analysis, and HRV testing. Pearson's or Spearman's correlation and linear regression analyses were performed where appropriate to assess the relationship between FTLM ratio, BMI, and HRV.

RESULTS: Both BMI and FTLM showed significant positive correlation with normalized LF power and LF-HF ratio and a negative correlation with normalized HF power, RMSSD, and pNN50. However, FTLM ratio showed a stronger association with HRV parameters than BMI and could explain a greater percentage of the variability in LF-HF ratio (32% compared to 18.4%, $P < 0.001$).

CONCLUSION: Assessment of both fat and lean mass, expressed as a ratio, is a better index of quantifying adiposity and predicting the influence of altered body composition on cardiometabolic health.

Keywords:

Anthropometry, body fat distribution, body mass index, cardiovascular disease, heart rate

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Introduction

Obesity, defined as accumulation of excess adipose tissue, has become a global epidemic. According to a report from the World Health Organization (WHO), over 1.9 billion persons aged 18 and older were overweight, with over 650 million of them being obese.[1] Fat-to-lean mass ratio (FTLM ratio) is a novel anthropometric index defined as the ratio between total body fat and total body lean mass.[2] Although body mass index (BMI) forms the basis for the definition of obesity and is strongly associated with multiple metabolic disorders, several confounders can skew this parameter, resulting in incorrect interpretations of the predicted risk. BMI does not reflect age-related changes and its relationship with body fat percentage (BF%) is nonlinear and differs based on gender as well. Hence, BMI has been shown to have poor sensitivity and specificity.[3] Further, evidence also shows that tropical south Asian regions like India and China have a specific "thin-fat phenotype," and these are individuals with normal BMI but an abnormally high BF%.[4,5] BMI ceases to be an adequate predictor of cardiometabolic

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risk in such individuals. These shortcomings are the prime factor that drives the discovery and development of novel anthropometric indices such as FTLM ratio. Unlike BMI, the measurement of FTLM ratio is usually done through direct approaches such as bioelectrical impedance and the values estimated by bioimpedance method have been found to be comparable with those obtained by dual energy X-ray absorptiometry (DEXA).[6]

Total body fat takes account of the adipose tissue, the primary site of energy storage while lean mass takes account of muscle mass, organs, and bone which are the site of energy expenditure.[7] Direct measurement of BF% can overcome the deficiencies of BMI as a surrogate of adiposity, but the use of BF% as the gold standard of adiposity is an incomplete solution as it doesn't consider lean body mass.[8] The balance of fat mass to lean body mass is essential for health, and assessment of both in relation to each other would be appropriate in predicting the influence of adiposity and altered body composition on cardiometabolic health.[2] Hence, FTLM ratio can account for the state of the cardiometabolic health more completely than fat percentage alone.[7]

Heart rate variability (HRV) is a non-invasive measure of physiological beat-to-beat variation in heart rate that characterize the interplay between the sympathetic and parasympathetic limbs of the autonomic nervous system.[9] HRV measurements provide an objective assessment of cardiac autonomic function and are an early predictor of cardiovascular risk.[10] Changes in autonomic activity associated with the condition of being overweight/obese is a well-established finding in the literature.[11]

Previous studies have shown FTLM ratio to be strongly associated with glucose metabolic disorders and insulin resistance.[2,7,12] However, data regarding the association between FTLM ratio and HRV is sparse. Also, to the best of our knowledge, a study comparing BMI and FTLM ratio regarding their association with HRV parameters, as to which is a better predictor of cardiovascular risk, has not been conducted thus far. Hence, in this study we intend to compare the associations of FTLM ratio and BMI with HRV.

Materials and Methods

Study design and setting

This was a cross-sectional analytical study conducted in the Department of Physiology, JIPMER, Puducherry, India. The study was approved by Institute Research Monitoring committee and Institutional Ethics committee (Human) (JIP/IEC-OS/2022/238). Before the commencement of the study, the procedure details were explained to the participants and written informed consent was obtained.

Study participants and sampling

Apparently healthy male adults aged 18–30 years in the BMI range of 18.5–29.9 kg/m^2 (as per Asia-Pacific classification of BMI)[13] were considered for the study. Individuals with known history of hypertension, cardiovascular disease, diabetes mellitus and metabolic disorder, endocrine disorder, history of smoking and alcohol on drugs affecting autonomic function were excluded.

Sample size calculation

A previous study showed the correlation coefficient between BMI and LF/HF ratio was 0.39.[14] Sample size was estimated to be 88 with expected correlation coefficient of HRV with BMI as 0.4 and HRV with FTLM ratio as 0.65 at 5% level of significance and 90% power. Convenience sampling technique was used.

Procedure

The participants were asked to report to autonomic function testing laboratory in the Department of Physiology in our Institute, 2 hours after food and in loose clothing.

Personal details

Data regarding age, dietary pattern (veg/non-veg), frequency of junk food intake, and level of physical activity were obtained from each participant. Physical activity was assessed using the International Physical Activity Questionnaire–Short Form (IPAQ-SF) a self-administered questionnaire, comprising of a set of four questionnaires, that can be used to obtain internationally comparable data on health-related physical activity over the last 7 days.[15]

Anthropometric assessment

Height was measured using a wall-mounted stadiometer (BHH6, Easy Care, Mumbai, India), to the nearest millimeter. Weight was measured using a digital weighing machine (MS 4900, Charder Electronic Co. Ltd, Taichung, Taiwan). The calculation of BMI was done using Quetelet's index (BMI = weight (kg)/[height (m)]^2). Waist circumference was taken as the narrowest circumference between the lower costal border of the tenth rib and the top of the iliac crest. The circumference at the level of greatest posterior protuberance of the buttocks was measured as hip circumference. A non-elastic measuring tape (Cescrof, Porto Alegre/RS) was used to measure waist circumference and hip circumference (centimeters). Waist-to-hip ratio and waist-to-height ratio were calculated.

Basal cardiovascular parameters

After giving 10 minutes of supine rest, basal heart rate (BHR), systolic blood pressure (SBP), and diastolic blood pressure (DBP) were recorded using automated blood pressure monitor (HEM – 8712, Omron, Kyoto, Japan).

Body composition analysis

Body composition was measured by bioimpedance method using automated body composition analyzer (Bodystat Quadscan 4000, VacuMed, Ventura CA). From the measured impedance, body composition parameters like BF%, fat weight, lean mass percentage, lean mass weight, FTLM ratio were derived.

Short-term HRV analysis

It was analyzed from the lead II ECG recorded for 5 minutes, during rest phase, using BIOPAC MP 150 data acquisition system (BIOPAC Inc., USA). RR tachogram was procured from lead II ECG, and the HRV indices were derived using Kubios software version 3.5 (Finland). Time and frequency domain analysis was done. Time domain indices computed were SDNN, RMSSD, NN50, pNN50 and frequency domain indices computed were VLF (ms^2), LF (ms^2), HF (ms^2), total power (ms^2), LF (n.u.), HF (n.u.), and LF/HF ratio.

Data analysis

Statistical analysis was performed using IBM SPSS Statistics for Windows, Version 25.0. (IBM Corp, Armonk, NY). The categorical variables were expressed as proportions. The continuous variables, such as heart rate, blood pressure, HRV parameters, etc., were expressed as mean with standard deviation or median with interquartile range based on distribution of data. Pearson's correlation or Spearman's rank correlation was used to assess correlation between FTLM, BMI, and HRV parameters based on distribution of data. Linear regression was performed to derive the equation to assess the relationship between FTLM and HRV and, between BMI and HRV. Correlation coefficient and R^2 were used to compare the association of FTLM vs BMI with HRV parameters. All statistical analysis was carried out at 5% level of significance.

Ethical considerations

The procedure and conduct of the study were approved by the Ethics Committee of our institute. The procedure was completely non-invasive and was deemed to be of minimal risk to participants.

Results

In this cross-sectional study, we recruited 88 apparently healthy male adults aged 18-30 years in the BMI range of 18.5–29.9 kg/m^2. Of the 88 participants 42 (47.72%) had normal BMI, 12 (13.64%) were overweight, and 34 (38.64%) were pre-obese. BMI was classified according to the WHO Asian Criteria for defining obesity.[13] Table 1 describes the anthropometric and body composition parameters among the participants. Table 2 shows frequency distribution of dietary pattern and physical activity level among the participants.

Basal cardiovascular parameters among the participants. The average values were, basal HR 82.00 beats/min (IQR-11.00), SBP 117 mmHg (IQR-4.00), and DBP 78 mmHg (IQR-7.00).

Table 3 depicts HRV parameters.

Table 1: Anthropometric and body composition parameters (*n*=88)

Anthropometric parameters	
Age (years)	20.74±1.22
Weight (Kg)	71.49±10.67
Height (m)	1.72±6.72
Waist (cm)	82.99±7.89
Hip (cm)	98.04±6.50
BMI (kg/m^2)	23.88±3.00
WHR	0.85±0.05
WHtR	0.48±0.05
Body composition parameters	
Fat %	17.24±3.89
Fat mass (kg)	12.56±4.30
Lean mass %	82.76±3.89
Lean mass (kg)	58.92±7.43
FTLM	0.21±0.06

The values are expressed in Mean±SD. BMI=Body mass index, WHR=Waist-to-hip ratio, WHtR=Waist-to-height ratio, FTLM=Fat-to-lean mass ratio

Table 2: Frequency distribution of dietary pattern and physical activity

Characteristics	Participants (*n*=88)	
	Frequency (*n*)	Percentage
Dietary Pattern		
Non-Veg	86	97.7
Veg	2	2.3
Junk Food		
No junk food	7	8.0
Once in a day	3	3.4
Once weekly	21	23.9
Twice weekly	24	27.3
Thrice weekly	17	19.3
>Thrice weekly	16	18.2
Physical activity		
Low	31	35.2
Moderate	48	54.6
High	9	10.2

The values are expressed as frequency with percentage. Physical activity was assessed using International Physical Activity Questionnaire–Short Form (IPAQ-SF)

Table 4 shows correlation of short-term HRV indices with BMI, FTLM ratio, and BF% among the participants. FTLM ratio and BF% showed higher correlation coefficients and greater levels of significance compared to BMI with the HRV parameters.

Table 5 shows simple linear regression of LF-HF ratio with BMI and FTLM ratio among the participants. Simple linear regression of LF- HF ratio and FTLM, LF-HF ratio and fat % and LF-HF ratio and BMI were statistically significant ($P < 0.001$). However, the FTLM ratio could explain 32% of the variability seen in LF-HF ratio ($R^2 = 0.320$), the fat % could explain 30% of the variability seen in LF-HF ratio ($R^2 = 0.3048$) while BMI could explain only 18.4% ($R^2 = 0.184$).

Table 3: Heart rate variability parameters among the participants

HRV parameters	Participants (*n*=88)
Short-term HRV parameters	
Time-domain Indices	
RMSSD (ms)	49.45 (38.02)
SDNN (ms)	43.82 (28.93)
NN50 (count)	88.50 (103.30)
pNN50 (%)	28.56 (32.31)
Frequency domain Indices	
TP (ms^2)	1721.44 (2781.29)
LF (ms^2)	671.06 (806.74)
HF (ms^2)	701.83 (1303.51)
LF (n.u.)	53.66 (28.81)
HF (n.u.)	46.34 (28.81)
LF/HF ratio	1.16 (1.12)

The values are expressed in median (inter-quartile range). RMSSD=Square root of mean of the sum of the squares of differences between adjacent NN intervals, SDNN=Standard deviation of all NN interval, NN50=Number of pairs of adjacent NN intervals differing by >50 ms in entire recording, pNN50=percentage of NN_{50}, LF=Power in low-frequency range (0.04–0.15 Hz), LF (n.u.)=LF power in normalized units, HF=Power in high-frequency range (0.15–0.4 Hz), HF (n.u.)=HF power in normalized units, TP=Total power, LF/HF ratio=Ratio of LF (ms^2)/HF (ms^2)

Discussion

Obesity, as a condition, is associated with increased all-cause mortality and morbidity in patients.[16] Changes in autonomic activity associated with the condition of being overweight/obese is a well-established finding in literature and has been the underlying pathophysiological mechanism in the onset of the major co-morbidities namely, diabetes mellitus and cardiovascular disease.[11,17] HRV analysis has been shown to be able to detect cardiac autonomic dysfunction earlier than traditional autonomic function tests.[18]

This risk seems to be a correlate of the adiposity above the normal physiological limits. BMI is the most widely adopted anthropometric surrogate of adiposity.[19] Although BMI is highly accessible it is plagued by several demerits. Chiefly, it does not discriminate between fat mass and other contributors to body mass like bone or lean mass. It is primarily a measure of excess weight and not excess fat.[19] Body fat percentage has been put forth as a better parameter, however, it does not consider another significant component, the lean mass. Recent studies have revealed that decreased skeletal mass is related to the risk of development of cardiometabolic disorders. This implies that a parameter that assesses both fat mass and lean body mass could be a more appropriate indicator of cardiovascular health. As fat and muscle are interconnected physiologically and biochemically, an imbalance between them can synergize to increase the risk of developing glucose metabolic disorders.[2] Hence, we hypothesized that FTLM ratio would be a better predictor of HRV than BMI.

In our study, there was significant positive correlation between BMI and HRV parameters such as LF-HF

Table 4: Correlation of short-term HRV indices with BMI, fat-to-lean mass ratio (FTLM), and fat %

Parameters	Participants (*n*=88)					
	BMI (kg/m^2)		FTLM		Fat %	
Short-term HRV indices	ρ	*P*	ρ	*P*	ρ	*P*
SDNN (ms)	-0.099	0.359	-0.255	0.017	-0.256	0.016
RMSSD (ms)	-0.221	0.038	-0.365	<0.001	-0.365	<0.001
NN50 (count)	-0.245	0.021	-0.368	<0.001	-0.357	0.001
pNN50	-0.240	0.024	-0.358	0.001	-0.368	<0.001
TP (ms^2)	-0.080	0.456	-0.271	0.011	-0.273	0.010
LF (ms^2)	0.158	0.142	-0.020	0.856	-0.023	0.830
HF (ms^2)	-0.231	0.031	-0.419	<0.001	-0.420	<0.001
LFnu	0.447	<0.001	0.485	<0.001	0.484	<0.001
HFnu	-0.447	<0.001	-0.485	<0.001	-0.484	<0.001
LF/HF ratio	0.447	<0.001	0.485	<0.001	0.484	<0.001

Data analysis was done by Spearman's rank correlation. SDNN=Standard deviation of all NN intervals, RMSSD=Square root of the mean of the sum of the squares of differences between adjacent NN intervals, NN50=Number of pairs of adjacent NN intervals differing by >50 ms in entire recording, pNN50=percentage of NN_{50}, TP=total power, LFnu=LF power in normalized units, HFnu=HF power in normalized units, LF/HF ratio=Ratio of LF (ms^2)/HF (ms^2), FTLM=Fat-to-lean mass ratio. *P*<0.05 is considered statistically significant

Table 5: Simple linear regression of LF-HF ratio with body mass index, fat-to-lean mass ratio, and fat %

Variables	Regression Coefficient β	R^2	*F* (df)	*P*
BMI (kg/m²)	0.150	0.184	19.378 (1,86)	<0.001***
FTLM	10.417	0.320	40.485 (1,86)	<0.001***
BF%	0.149	0.305	37.705 (1,86)	<0.001***

Dependent Variable: LF-HF ratio. LF/HF ratio=Ratio of LF (ms²)/HF (ms²), BMI=Body mass index, FTLM=Fat-to-lean mass ratio, BF%=Body fat %

ratio and LF (nu). There was also significant negative correlation between BMI and HF (nu) and HF (ms²). A previous study with similar methodology also reported a significant positive correlation between BMI and LF-HF ratio.[20] There was significant negative correlation between BMI and RMSSD and pNN50 in our study. A previous study also reported a similar negative correlation between these parameters and BMI.[21] Several studies have reported that an increase in BMI is associated with increase in sympathetic and decrease in parasympathetic activities. Time-domain indices in HRV analysis; RMSSD, SDNN, NN50 and pNN50 represent the high-frequency variations in short-term recording of ECG, which is mediated by the vagal tone.[21] Among frequency domain indices, total power depicts overall HRV, LF power, LF (n.u.) depicts sympathetic tone and HF power and HF (n.u.) represents sympathetic tone. LF/HF ratio has been the indicator of sympathovagal balance. From our findings also, we support that an increase in BMI would increase sympathetic tone and decrease vagal tone. FTLM had significant negative correlation with SDNN, RMSSD, NN50 and pNN50 with higher correlation coefficients and greater levels of significance compared to BMI. FTLM showed a significant positive correlation with LF (nu) and LF-HF ratio. FTLM had significant negative correlation with HF (nu) and with TP. Also, a very similar association was found between BF% and HRV parameters.

In this study, we have found an association between BMI and parameters of HRV which have been reported by many studies. Although the association between FTLM ratio and parameters of HRV was similar to BMI, we found marginally stronger correlation than BMI. Further, the regression analysis revealed that FTLM ratio could explain 32% of the variability seen in LF-HF ratio ($R^2 = 0.320$) while BMI could explain only 18.4% ($R^2 = 0.184$). Hence, the association between LF-HF ratio and FTLM ratio was stronger than its association with BMI. This implies that FTLM is a better predictor of LF-HF ratio than BMI. In fact, BF % alone could explain 30% variation in HRV, which still supports FTLM as a better indicator of cardiovascular health. In coherence with our findings, in a study conducted among adults, it was observed that higher fat mass and lower muscle mass had poorer parasympathetic activity,[22] and in another study among children, fat-free mass was found to have a favorable association with parasympathetic activity.[23] Further, FTLM already been found to be correlated to risk stratification in metabolic syndrome.[8]

Even though BMI has shown significant association with the parameters of HRV, BMI has been found to be less specific and sensitive in measuring the adverse effects of obesity. The necessity for better adiposity indices was realized. Though BF % emerged as a measure of quantifying body fat mass, it was an incomplete solution. BF% is affected by variation in both fat mass and lean mass. Individuals with varying BF% can have similar fat mass and different lean mass or vice versa. Hence, although body fat percent represents two components of body composition, it actually cannot delineate them.[2] Hence, assessment of both fat and lean mass, which are primary sites of energy metabolism, would give a better idea about cardiometabolic status. Assessment of these entities as a ratio, which expresses the balance between them, would be a better index of quantifying adiposity and thereby, the underlying energy metabolism. Hence, FTLM ratio is a better index of body composition. Also, as FTLM ratio is estimated through BIA that has shown improved accuracy, and it is superior to BMI as a measure of body composition. From our study, we found that FTLM ratio can predict HRV better than BMI.

Strengths and weaknesses

Our study provides evidence for the utility of FTLM ratio and demonstrates its statistical superiority to BMI in predicting HRV. This finding was evident in body composition analysis using BIA, which is a more affordable and safer modality compared to DEXA and hence suitable for use as a screening tool.

We had a moderate sample size, a study with larger sample size can further establish our findings. We also confined our study population to males as we found it infeasible to establish proper controls for the variation in HRV due to the menstrual cycle in our setting. Further, studies are needed to establish these findings in females.

Conclusion

FTLM ratio has a stronger association with HRV and can predict 32% of variation in HRV, when compared to BMI, which could predict only 18% of the variation in HRV. Hence, FTLM ratio would prove to be a better predictor of HRV than BMI.

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Abbreviations

Abbreviation	Expansion
BF%	Body Fat Percentage
BHR	Basal Heart Rate
BIA	Bioelectrical Impedance Analysis
BMI	Body Mass Index
DBP	Diastolic Blood Pressure
DEXA	Dual Energy X-ray Absorptiometry
ECG	Electrocardiogram
FTLM ratio	Fat-to-lean mass ratio
HF	High Frequency
HR	Heart Rate
HRV	Heart Rate Variability
IPAQ-SF	International Physical Activity Questionnaire–Short Form
IQR	Interquartile Range
LF	Low Frequency
RMSSD	Square root of the mean of the sum of the squares of differences between adjacent NN intervals
SBP	Systolic Blood Pressure
SDNN	Standard Deviation of NN intervals
TP	Total Power
VLF	Very Low Frequency
WHO	World Health Organization

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Conflicts of interest

There are no conflicts of interest.

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