Resting Heart Rate Variability is Independently Associated with Visceral Fat Rating Scores in Saudi Adult Males

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Abstract

Background: Visceral adipose tissue (VAT) may be a specific modifiable contributor to body composition-related autonomic impairment.

Objectives: To compare heart rate variability (HRV) between groups stratified by visceral fat rating (VFR) and compare associations between HRV and body composition metrics.

Methods: A cross-sectional study was conducted on healthy men (n=99, age=37.8±13.4 years, body mass index [BMI]=26.9±4.6 kg/m²). HRV was derived from 5-minute electrocardiographic recordings. Body composition (body fat percentage, VFR, and muscle mass to visceral fat ratio [MMVFR]) was estimated using tetrapolar bioelectrical impedance analysis. Participants were categorized into groups according to VFR: G1 (VFR=1-8); G2 (VFR=9-12); and G3 (VFR>12). Age-adjusted comparisons were made between groups. Independent associations were quantified with multiple linear regressions. P <0.05 was significant.

Results: Root-mean square of successive differences (RMSSD) and standard deviation of normal RR intervals (SDNN) were higher for G1 vs. G2 and G3 (p<0.05). Low-frequency power (LF) was higher in G1 than in G2 (p<0.05). VFR and MMVFR were negatively associated with SDNN, RMSSD, LF, and HF (p<0.05). After adjusting for age, BMI, and systolic and diastolic blood pressure, VFR was significantly predictive of RMSSD, SDNN, and HF (p=0.002,–0.027), and MMVFR was significantly predictive of RMSSD and SDNN (p=0.020,–0.023).

Conclusions: Men in the lowest VFR category had the highest HRV. VFR was more strongly associated with HRV than body fat percentage and MMVR. Time domain parameters were more sensitive to VAT than frequency domain parameters. HRV parameters could be the primary parameters of interest in tracking cardiac-autonomic status in response to interventions targeting VAT reduction.

Keywords: Intra-Abdominal Fat; Heart Rate; Autonomic Nervous System.
reported stronger associations between HRV and indicators of VAT.\textsuperscript{14-16} Thus, central adiposity seems to be influencing the association between body fat and cardiac-autonomic function.

VAT can be estimated with tetrapolar bioelectrical impedance analysis (BIA), which serves as a convenient alternative to criterion laboratory measures or basic anthropometry.\textsuperscript{17} To our knowledge, only one previous investigation has quantified associations between BIA-derived VAT and HRV in healthy adults. Results showed lower vagal-mediated HRV in overweight healthcare students versus an age-matched control group. However, groups were categorized by body mass rather than by VAT, and associations with HRV were not compared between the various markers of body composition.

Skeletal muscle supports metabolic health and physical functioning.\textsuperscript{18} Muscle mass expressed relative to VAT, indexed by the ratio of muscle mass to visceral fat ratio (MMVFR), seems to be a relevant indicator of metabolic function. For example, BIA-derived MMVFR has been associated with non-alcoholic fatty liver disease and liver fibrosis\textsuperscript{19} and aids in the detection of Metabolic Syndrome in young adults.\textsuperscript{20} Thus, MMVFR seems to be a relevant health marker, but our understanding of its association with cardiac-autonomic functioning in healthy adults is limited.

Clarification of how BIA-derived body composition characteristics influence HRV may be of clinical relevance for assessing risk and guiding treatment. Therefore, the purpose of this investigation was to test the hypothesis that HRV differs between participants as a function of VAT categorization and that indexes of VAT will be more strongly associated with HRV than relative fat mass in healthy adult men.

**Methods**

**Study settings**

This cross-sectional study was conducted at the Department of Physiology and Exercise Physiology laboratories, within the College of Sport Sciences and Physical Activity of King Saud University (KSU). Ninety-nine healthy adult Saudi male subjects aged 20-60 years were eligible for participation. Convenience sampling was used to recruit volunteers who were approached via bulletin boards, posters, and social media announcements and those who expressed interest in participating were informed of all...
study procedures. Inclusion criteria included: healthy men non-smokers; those free of metabolic, orthopedic, and neurological disorders; no history of previous angina or myocardial infarction and BMI < 40 kg/m². Professional athletes were excluded, but highly recreationally active individuals were included. This study was approved by the Institutional Review Board of KSU, Riyadh, Saudi Arabia (IRB No. E-18-3381). All subjects provided written informed consent and all procedures were performed as per the relevant guidelines and protocols. The main data of the article is summarized in the Central Illustration.

Study procedures

Participants were instructed to avoid intake of caffeinated drinks and vigorous exercise training on the day before the laboratory visit for morning assessment in an overnight fasted state. Morning beverages, including water, were restricted to control for their confounding influence on HRV. Blood pressure and anthropometric measurements were performed with standard procedures that comprised blood pressure, demographics, body composition, and electrocardiogram (ECC) assessment.

Blood pressure and anthropometric measurements

Height was measured using a stadiometer (Seca 213, Seca GmbH & Co., Hamburg, Germany), and body weight was measured with a digital scale (PD100 ProDoc, Detecto Scale, Cardinal, Webb City, MO, USA). Waist circumference (WC) was measured in cm at the umbilicus. All values were adjusted to the nearest 0.1 cm. Body mass index (BMI) was computed by dividing weight by height in squared meters. Resting heart rate and systolic and diastolic blood pressures were estimated by an automated digital sphygmomanometer (HEM-7121, Omron, Shimogyo-ku, Kyoto, Japan).

Body composition estimation

A multi-frequency segmental machine (MC-980MA, Tanita Corporation, Tokyo, Japan) that delivers 50-1000 kHz currents was used to estimate body composition parameters. Participants stood barefooted on the scale whilst holding the electrodes with slight glenohumeral abduction. The height of each subject was measured and recorded. Participants were subsequently weighed and body composition values were indirectly estimated using the device. The following body composition measures were collected: body fat percentage (BF%), body water percentage, muscle mass, bone mass, and visceral fat rating (VFR). VFR is provided as a specific rating (0–59 points). Ratings from 1 to 12 points indicate that the subject has a healthy visceral fat level, while ratings from 13 to 59 indicate that the subject has an excess visceral fat level. VFR has been widely applied in clinical research as an indirect index of visceral fat. The MMVR was subsequently computed.

Heart rate variability assessment

All participants underwent 12-lead standard ECG testing in the supine position following the body composition assessment. We used a computerized ECG data acquisition device (PL3516 Power Lab 16/35, AD Instruments Pty Ltd. New South Wales, Australia) with 16 analog input channels. A 10-minute ECG recording was performed while signal quality was monitored by a researcher. A customized software (LabChart v. 8.1.13 Windows, AD Instruments Pty Ltd. New South Wales, Australia) was used for computing HRV variables. Artifacts and ectopic beats were processed using a standardized filter by the software-automated “Beat Classification” tool, which categorizes beats according to activity and isoelectric noise, and removes artifacts generated by movement, electrical interference, and ectopic beats. HRV parameters were derived from a 5-min criterion segment (i.e., min 5-10) and the first 5-min were discarded for stabilization. Time-domain parameters recorded for analysis were the average time between RR intervals (Average RR), the standard deviation of normal RR intervals (SDNN), and the root mean square of the successive differences of normal RR interval differences (RMSSD). Frequency domain analysis of HRV by fast Fourier transform method included assessment of low frequency (LF), high frequency (HF), and the low LF/HF ratio. Average RR reflects resting heart rate, RMSSD and HF reflect parasympathetic modulation, SDNN, and LF reflect global variability with sympathetic and parasympathetic influence.

Statistical analysis

For data entry and statistical analysis, SPSS software (version 20.0 Chicago, IL, USA) was used. Continuous variables were presented as mean and standard deviation (SD) while categorical variables were expressed as frequencies and/or percentages (%). Continuous variables were checked for normality using the Kolmogorov-Smirnov test. The data following non-normal distributions were log-transformed. Participants were categorized into 3 groups (G) according to their VFR: G1 (VFR = 1-8), G2 (VFR = 9-12), and G3 (VFR > 12). HRV and body fat characteristics are both associated with age, which may confound associations between HRV and body fat characteristics. Thus, groups stratified by VFR were compared for demographic characteristics and HRV parameters by one-way analysis of covariance (ANCOVA) adjusting for age and all the assumptions necessary for the use of ANCOVA were met. The chi-square test was used to compare percentage distributions between different groups. Post-hoc comparisons were performed using Bonferroni and Tamhane tests. Bivariate associations between raw HRV and body composition parameters were assessed with Spearman’s r. Finally, separate multiple linear regressions were performed with BF%, VFR, and MMVFR as predictors to assess the comparative predictive value of each with HRV parameters. Models included age, BMI, and systolic and diastolic blood pressure as covariates. P <0.05 was considered statistically significant.

Results

Demographic values for the entire group (n = 99) and groups stratified by VFR are displayed in Table 1. G1 was significantly younger than G2 and G3. After controlling for age, G1 had significantly lower body mass, muscle mass, and waist circumference, along with lower body fat characteristics than G2 and G3. In addition, G3 had significantly higher age-adjusted waist circumference and body fat characteristics than G2.

The time-domain HRV comparison revealed significant between-group differences for RMSSD and SDNN, but not Average RR (Table 2). Post-hoc analyses demonstrated that
RMSSD and SDNN were significantly higher for G1 than G2 and G3, independent of age. Comparison of frequency domain HRV revealed significant between-group differences for LF, but not HF or LF/HF (Table 3). Post-hoc analyses determined that LF was significantly higher in G1 than in G2, independent of age.

Scatterplots comparing associations between RMSSD and Average RR with VFR are presented in Figure 1.

After covariate adjustment in regression analyses, VFR was significantly predictive of RMSSD, SDNN, and HF, and MMVFR was significantly predictive of RMSSD and SDNN. Standardized Beta coefficients are presented in Table 4.

**Discussion**

The aims of this investigation were 1) to compare HRV between groups stratified by BIA-derived VFR and 2) to compare associations between HRV and body composition metrics in healthy Saudi men. The main findings were that individuals in the lowest VFR category had significantly higher age-adjusted RMSSD, SDNN, and LF than groups of higher VFR categorization. In addition, HRV parameters (RMSSD, SDNN, HF) were more strongly associated with VFR than BF% and MMVFR after controlling for age, BMI, and systolic and diastolic blood pressure.

In support of our hypothesis, HRV metrics of vagal influence (RMSSD) and global variability (SDNN, LF) varied as a function...
Table 3 – Frequency domains analysis of all subjects and subgroups based on visceral fat rating

<table>
<thead>
<tr>
<th>Variables</th>
<th>All</th>
<th>G 1 (VFR = 1-8)</th>
<th>G 2 (VFR = 9-12)</th>
<th>G 3 (VFR &gt; 12)</th>
<th>p value</th>
<th>p value adjusted</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>99</td>
<td>51</td>
<td>30</td>
<td>18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LF (ms²)</td>
<td>2.884 ± 0.599</td>
<td>3.106 ± 0.459</td>
<td>2.620 ± 0.732</td>
<td>2.766 ± 0.445</td>
<td>.007</td>
<td>.027</td>
</tr>
<tr>
<td>HF (ms²)</td>
<td>2.928 ± 0.674</td>
<td>3.229 ± 0.459</td>
<td>2.584 ± 0.828</td>
<td>2.766 ± 0.514</td>
<td>.004</td>
<td>.284</td>
</tr>
<tr>
<td>LF/HF</td>
<td>-0.130 ± 0.330</td>
<td>-0.190 ± 0.347</td>
<td>-0.155 ± 0.231</td>
<td>0.081 ± 0.349</td>
<td>.001</td>
<td>.496</td>
</tr>
</tbody>
</table>

Data is presented as mean ± SD; G: group; VFR: visceral fat rating; N: number of participants; LF: low frequency; HF: high frequency. One-way analysis of covariance (ANCOVA) was used for group comparisons.

FIGURE 1 – Scatter plots of VFR relationships with RMSSD and Average RR. VFR: visceral fat rating; RMSSD: Root-mean square of successive differences.

Figure 1 – Scatter plots of VFR relationships with RMSSD and Average RR. VFR: visceral fat rating; RMSSD: Root-mean square of successive differences.

Abdominal obesity is associated with greater resting sympathetic activation than peripheral obesity, despite similar baroreflex impairment between obese groups, implying mechanisms of metabolic origin. Hyperglycemia, hyperinsulinemia, and insulin resistance are associated with both abdominal obesity and sympathetic hyperactivity, leading to reduced HRV and increased cardiometabolic risk. However, metabolic abnormalities as described above are linked to pro-inflammatory states. VAT contributes to systemic inflammation via its secretion of adipokines such as tumor necrosis factor-α, interleukin-6, C-reactive protein, and angiotensinogen. It’s been demonstrated that low-grade inflammation is associated with attenuated HRV in middle-aged and older adults. Furthermore, oxidative stress from adipokine-related dysregulation of reactive oxygen species is also thought to contribute to autonomic imbalance. Thus, VAT may promote dysfunction of the ANS via the effects of its secretions, but further study aimed at clarifying mechanisms is required.
Table 4 – Multiple linear regression analysis with BF%, VFR, and MMVFR as predictors, adjusting for covariates of age, body mass, and systolic and diastolic blood pressure

<table>
<thead>
<tr>
<th>Dependent Variable in Regression Models</th>
<th>Standardized Coefficients</th>
<th>t</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>BF%</td>
<td>-0.303</td>
<td>-1.865</td>
<td>.065</td>
</tr>
<tr>
<td>VFR</td>
<td>-0.083</td>
<td>-0.496</td>
<td>.621</td>
</tr>
<tr>
<td>MMVFR</td>
<td>-0.007</td>
<td>-0.042</td>
<td>.966</td>
</tr>
<tr>
<td>Average RR (S)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SDNN (ms)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BF%</td>
<td>-0.197</td>
<td>-1.307</td>
<td>.194</td>
</tr>
<tr>
<td>VFR</td>
<td>-0.421</td>
<td>-3.206</td>
<td>.002</td>
</tr>
<tr>
<td>MMVFR</td>
<td>0.283</td>
<td>2.372</td>
<td>.020</td>
</tr>
<tr>
<td>RMSSD (ms)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BF%</td>
<td>-0.184</td>
<td>-1.221</td>
<td>.225</td>
</tr>
<tr>
<td>VFR</td>
<td>-0.410</td>
<td>-3.117</td>
<td>.002</td>
</tr>
<tr>
<td>MMVFR</td>
<td>0.275</td>
<td>2.305</td>
<td>.023</td>
</tr>
<tr>
<td>LF (ms²)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BF%</td>
<td>-0.032</td>
<td>-0.205</td>
<td>.838</td>
</tr>
<tr>
<td>VFR</td>
<td>-0.167</td>
<td>-1.038</td>
<td>.302</td>
</tr>
<tr>
<td>MMVFR</td>
<td>-0.067</td>
<td>-0.432</td>
<td>.667</td>
</tr>
<tr>
<td>HF (ms²)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BF%</td>
<td>-0.089</td>
<td>-0.557</td>
<td>.579</td>
</tr>
<tr>
<td>VFR</td>
<td>-0.317</td>
<td>-2.248</td>
<td>.027</td>
</tr>
<tr>
<td>MMVFR</td>
<td>0.219</td>
<td>1.723</td>
<td>.089</td>
</tr>
<tr>
<td>LF/HF</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BF%</td>
<td>0.044</td>
<td>0.258</td>
<td>.797</td>
</tr>
<tr>
<td>VFR</td>
<td>0.083</td>
<td>0.477</td>
<td>.635</td>
</tr>
<tr>
<td>MMVFR</td>
<td>0.120</td>
<td>0.702</td>
<td>.484</td>
</tr>
</tbody>
</table>

Limitations of our study include its cross-sectional design, utilization of only supine HRV recordings, and lack of additional important covariates such as blood biomarkers and physical activity. Lack of respiratory control during ECG assessment may also be considered a limitation. Moreover, our relatively small sample size and inclusion of only men limit the generalizability of our findings to the broader population. Finally, VAT was estimated by BIA, which is of lower quality relative to criterion approaches such as magnetic resonance imaging.

Conclusions and recommendations

Higher visceral fat, as indexed by BIA-derived VFR, was associated with reduced HRV in a sample of healthy men. Associations remained statistically significant after age, BMI and systolic and diastolic blood pressure were held constant. VFR was more strongly associated with HRV when compared to body fat percentage and MMVFR. VAT and HRV are modifiable with lifestyle factors and can be self-monitored with commercially available devices. Our findings suggest that RMSSD and SDNN may be the most sensitive HRV parameters to changes in VAT, and therefore should be the primary parameters of interest in tracking cardiac-autonomic status in response to interventions targeting VAT reduction.

Acknowledgments

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Author Contributions

Conception and design of the research: Habib SS, Alkahtani S, Aljawini N, Flatt AA; Acquisition of data: Habib SS, Alkahtani S, Aljawini N, Habib SM; Analysis and interpretation of the data: Habib SS, Alkahtani S, Habib SM, Flatt AA; Statistical analysis: Habib SS, Flatt AA; Obtaining financing: Alkahtani S; Writing of the manuscript and Critical revision of the manuscript for content: Habib SS, Alkahtani S, Aljawini N, Habib SM, Flatt AA.

Potential conflict of interest

No potential conflict of interest relevant to this article was reported.

Sources of funding

There were no external funding sources for this study.

Study association

This study is not associated with any thesis or dissertation work.

Ethics approval and consent to participate

This study was approved by the Ethics Committee of the IRB of King Saud University under the protocol number E-183381. All the procedures in this study were in accordance with the 1975 Helsinki Declaration, updated in 2013. Informed consent was obtained from all participants included in the study.
References


