ISSN: 2454-1907
DOI: https://doi.org/10.29121/ijetmr.v5.i10.2018.296

IJETMR
International Journal of Engineering Technologies and Management Research
A Knowledge Repository

INFLUENCE OF THE RESPIRATORY SIGNAL IN HEART RATE VARIABILITY ANALYSIS IN THE RESPIRATORY PATTERN IN HEALTHY ELDERLY AND WITH COPD

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Abstract:

Motivation/Background: ***Cardiorespiratory interaction is known to cause a peak in the heart rate variability (HRV) spectrum, characterized as sinus arrhythmia. This study evaluates standard indexes of HRV spectral analysis with and without the influence of respiratory signal in elderly subjects with chronic obstructive pulmonary disease (COPD, N=14) and healthy lungs (N=14). In the last, all subjects controlled their breathing at 0.1 Hz (CGL) and breathed freely (CG).***

Method: ***Anthropometrical characteristics were similar, with increased heart rate in COPD (75±11.1 vs. 62±8.3 bpm). Cardiac and respiratory signals in supine position were recorded with a portable data acquisition system during 5 min and processed in frequency domain. To remove the influence of the respiration in HRV, a 2th order Butterworth band-stop filter, was applied to the RRi signal.***

Results: ***In CGL main respiratory frequency was significantly lower (ANOVA with post-hoc Turkey's test, α = 0.05) and with the influence of respiratory signal differed from without the influence of respiratory signal to HRV spectral analysis (Student t-test, α = 0.05) with increased low frequency contribution (51.0±11.4 vs. 42.0±11.6, respectively). PG and CG showed no significant differences in with or without influence of respiratory signal to HRV spectral analysis.***

Conclusions: ***The results of the present study have showed a low frequency respiration at 0.1 Hz provided an increase in low frequency and decrease in high frequency power spectral analysis, showing an error in the HRV analysis.***

Keywords: Heart Rate Variability; Spectral Analysis; Respiratory; Chronic Obstructive Pulmonary Disease; Breathing.

Cite This Article: Wollner Materko, Rhenan Bartels, Gabriel Casulari Motta-Ribeiro, Agnaldo José Lopes, Jurandir Nadal, and Alysson Roncally SilvaCarvalho. (2018). "INFLUENCE OF THE

ISSN: 2454-1907
DOI: 10.5281/zenodo.1473834

RESPIRATORY SIGNAL IN HEART RATE VARIABILITY ANALYSIS IN THE RESPIRATORY PATTERN IN HEALTHY ELDERLY AND WITH COPD." *International Journal of Engineering Technologies and Management Research,* 5(10), 1-8. DOI: https://doi.org/10.29121/ijetmr.v5.i10.2018.296.

1. Introduction

The analysis of heart rate variability (HRV) has been frequently showed as a noninvasive method for quantifying alterations in autonomic control of the heart rate fluctuations [1]. Spectral analysis of HRV has been used to assess sympathetic and parasympathetic contribution to heart rate control through frequency-specific oscillations of heart rate [2]. This analysis mainly consists of measuring the power into two spectral bands: low frequency (LF: 0.05-0.15 Hz), considered as reflecting mostly the sympathetic activity; and high frequency (HF: 0.15-0.5 Hz), associated with parasympathetic activity at the sinus node [3-5].

One important aspect of HRV is the respiratory modulation, characterized as sinus arrhythmia [6,7]. This cardiorespiratory interaction is known to cause a peak in the HRV spectrum, which occurs into the HF band in normal resting young adults, to whom this band was originally established. On one hand, increased respiratory rates may move this peak to a frequency higher than 0.5 Hz, causing the underestimation of vagal activity without significantly effect on spectral analysis of cardiovascular autonomic modulation in healthy subjects [8]. Conversely, the impact of respiration signal on HRV analysis is exacerbated when this signal falls within the LF band [9-11]. In this case, a problem of isolating two branches rises since respiration can entrain heart rate and blood pressure oscillations over the range of frequencies below 0.15 Hz [12-13].

The respiratory peak or the fundamental respiration frequency (FRF) can thus be used as a tool to estimate vagal activity, allowing the isolation of the two branches of autonomic nervous systems [14]. This FRF corrected analysis by frequency bands would eventually lead to a more accurate evaluation of HRV, representing a valuable tool in diagnosing people with autonomic dysfunctions, especially in patients with chronic obstructive pulmonary disease (COPD) [15,16]. Nevertheless, to our knowledge, no previous study [9,10,11,14] considered how controlled breathing affect HRV measurement in healthy and COPD subjects. Thus, the goal of the present study was to clarify the effect of respiratory signal on HRV parameters by comparing results in patients with COPD and a control group breathing normally or with an educated frequency of 0.1 Hz.

2. Materials and Methods

The study protocol was approved by the local Ethical Human Research Committee of Augusto Motta University Center (protocol: CAAE 52885116.6.0000.5235) and an informed written consent was obtained from all participants. The study was conducted according to the instructions of the Helsinki Declaration of 2008.

Subjects

This study was designed as a cross-sectional and twenty-eight elderly from both genders, 60–85 years old, were divided into two groups, fourteen subjects each: pathological group (PG) with a

ISSN: 2454-1907
DOI: 10.5281/zenodo.1473834

diagnosis of COPD, according to the Global Initiative for Chronic Obstructive Lung Disease [17]. In addition, no patient had severe or unstable cardiac disease, or any underlying comorbidity which could directly interfere with the performance of the tests. None of the recruited patients were involved in regular physical activity before participating in study. The control group divided into two comparable groups: that controlled their breathing at 0.1 Hz (CGL) and breathed normally (CG). All subjects were nonsmokers, with no history of cardiopulmonary disease, and none were taking any medication or using home oxygen therapy.

Anthropometric Measurements

Body weight was measured to the nearest 0.1 kg while the height was measured in centimeters using a mechanic scale with stadiometer (Filizola, Brazil) and body mass index was calculated as the weight divided by height squared (kg/m^2).

Experimental Procedures

The tests were conducted in a quiet room with temperature maintained at 22ºC. All volunteers were instructed to avoid strenuous activity in the 24 hours prior to each testing session and to avoid alcohol, caffeine as well as the consumption of large meals for, at least, three hours prior testing.

After anthropometric measurements, all subjects were instructed to lie in supine position for 5 min at rest while breathing normally and, posteriorly, the CG subjects were also asked to consciously control their breathing at 0.1 Hz (6 breaths\min) at random using a digital timer.

Data Collection

First, each cardiac and respiratory cycle were measured by a custom-made portable data acquisition, working at a sampling rate of 1000 Hz. The acquisition system is comprised of three modules: (1) acquisition module, responsible for the analog/digital conversion and data recording; (2) respiratory rate module, to measure the inspiratory and expiratory chest wall movements through a thoracic belt for piezoelectric plethysmography (EMSA, Brazil) and an amplifier with adjustable gain; and (3) heart rate module Polar® HRMI board (Sparkfun, USA), that generates a impulse for each QRS wave detected by a belt T31 (Polar®, Kenpele, Finland) positioned around the chest of each volunteer.

Before the frequency analysis, RR intervals (RRi) were determined by selecting peaks above a given threshold on the recorded train of impulses. The respiratory signal was low-pass filtered by a 4^{th} order Butterworth filter with cutoff at 3 Hz to remove spectral components outside the respiratory band. For emphasize the respiratory frequency, the recorded signal that estimate uncalibrated volume was digitally derived to obtain an uncalibrated flow signal [18].

Spectral Analysis

The sequence of RRi was interpolated by cubic splines and resampled with a frequency of 4 Hz to obtain an equally sampled signal. The spectral analysis was performed using the Welch Periodogram Method [2] (segments of 256 points with 128 points of overlap using Hanning window). All signal analysis was performed with programs written in Matlab version 6.5 (The MathWorks, USA).

The frequency representation of the flow signal was estimated using the same method as for the RRi. Thus, the highest peak identified in the spectra was considered as the FRF of each subject

ISSN: 2454-1907
DOI: 10.5281/zenodo.1473834

and a frequency band between FRF x 0.65 and FRF x 1.35 was assumed to represent the respiratory contribution in frequency analysis [14]. To remove the influence of the respiration in HRV, a 2th order Butterworth band-stop filter, in this respiratory range, was applied to the RRi signal.

Heart Rate Variability Analysis

The classical HRV spectral analysis was performed in the SinusCor Matlab package (Pulmonary Engineering Lab, PEB/COPPE/UFRJ, Brazil) [19] both before and after filtering the respiration contribution. The evaluated parameters were the spectral indexes: LF normalized (LFnu), HF normalized (HFnu) and LF/HF ratio, all computed as recommended by the Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology [2].

Statistical Analysis

Descriptive statistical analyses of the data were expressed as mean ± standard deviation. The Kolmogorov-Smirnov test confirmed the normality of distributions. The between groups difference in anthropometric characteristics was tested by Student's t-test for independent variables. Respiratory frequency was compared between groups by one-way analysis of variance (ANOVA), and the post-hoc Turkey's test was applied when significant differences occurred. Finally, HRV parameters with or without the influence of the respiratory signal were compared within groups (PG, CG and CGL) by means of a paired t-test. All tests assumed $\alpha = 0.05$ for statistical significance. All statistical analysis was performed in Matlab version 6.5.

3. Results and Discussions

Anthropometric characteristic of the subjects were similar between groups with low values of standard deviation (Table 1), values are mean ± standard deviation, showing no significant differences. The resting heart rate was higher in PG (75.0 ± 11.1 vs 62.0 ± 8.3, $p < 0.01$) than in GC.

Table 1: Anthropometric characteristics of enrolled subjects

Variables	**COPD**	**Control**	**P-value**
Age (years)	71 ± 7.2	68.4 ± 8.4	0.14
Height (cm)	164 ± 10	169 ± 7.3	0.06
Body mass (kg)	70.4 ± 9.6	73.2 ± 8.4	0.16
Body mass index (kg/m^2)	26.3 ± 3.9	26.1 ± 3.2	0.41
Resting heart rate (bpm)	75 ± 11.1	62 ± 8.3	< 0.01

The FRF corresponded to 0.31 ± 0.05 Hz for PG, 0.28 ± 0.04 Hz for CG and 0.11 ± 0.01 Hz for CGL, showing significant difference ($p < 0.01$) as presented in Table 2. The post-hoc test shows that only CGL have a FRF different from PG and CG ($p = 0.01$).

Table 2: Respiratory frequency for each subject of COPD (PG) and control group both breathing normally (CG) and with an educated frequency (CGL)

Subjects	**PG**	**CG**	**CGL**
1	0.26	0.33	0.10
2	0.25	0.28	0.09
3	0.33	0.25	0.11

ISSN: 2454-1907
DOI: 10.5281/zenodo.1473834

4	0.35	0.33	0.12
5	0.28	0.25	0.15
6	0.32	0.26	0.10
7	0.38	0.23	0.13
8	0.32	0.25	0.11
9	0.26	0.25	0.14
10	0.25	0.25	0.12
11	0.33	0.33	0.13
12	0.41	0.31	0.15
13	0.28	0.33	0.10
14	0.25	0.26	0.11
Mean ± SD	0.31 ± 0.05 Hz	0.28 ± 0.04 Hz	0.11 ± 0.01 Hz

When comparing the estimated HRV spectral indexes with and without the influence of respiration, the CGL showed significant decrease in LFnu and increase in HFnu, with subsequently decrease in LF/HF ratio, after the removal the respiration influence. However, the PG and CG showed no significant differences due this procedure (Table 3).

In the PG and CG, the FRF and respiratory signal are restricted to the HF area (Table 2). Interestingly, the PG group has the highest loading in the LF band, as marker of sympathetic activity, which may have contributed to discrimination in terms of COPD disease (Table 3). In contrast, CGL has the FRF shifted into the LF band of HRV (Table 3). When comparing both conditions of the control group, CGL showed a reduction in the HF and increase in the LF component of HRV (Table 3).

Table 3: Comparison of heart rate variability parameters in the frequency domains with and without the influence of the respiratory signal at rest. PG – COPD; CG – control group with normal breath and; CGL – with educated breath

Groups	**HRV Variables**	**with respiratory signal**	**without respiratory signal**	**P-value**
	LFnu (%)	50.2 ± 14.9	54.0 ± 16.5	0.220
PG	HFnu (%)	49.8 ± 15.0	46.0 ± 16.5	0.262
	LF/HF	1.2 ± 1.0	1.5 ± 1.1	0.262
	LFnu (%)	51.9 ± 14.7	56.5 ± 17.8	0.110
CG	HFnu (%)	48.1 ± 14.7	43.5 ± 17.8	0.215
	LF/HF	1.3 ± 1.0	1.9 ± 1.7	0.214
	LFnu (%)	51.0 ± 11.4	42.0 ± 11.6	0.023*
CGL	HFnu (%)	49.0 ± 11.4	58.0 ± 11.5	0.023*
	LF/HF	1.1 ± 0.5	0.8 ± 0.4	0.012*

Values are mean ± standard deviation *Significant difference in t-test

This study aimed to identify the differences in HRV spectral analysis with and without the influence of the respiratory signal, comparing results in patients with COPD and a healthy control group, which controlled their breathing at 0.1 Hz or breathed normally. During controlled

ISSN: 2454-1907
DOI: 10.5281/zenodo.1473834

breathing, LFnu and LF/HF indexes were reduced after correction for the respiratory signal frequency. That in general would provide more accurate results due to true localization of parasympathetic activity with HRV spectral analysis.

Respiration is a powerful modulator of heart rate variability and reflex control systems.[7] Abnormal respiratory modulation is often an early sign of autonomic dysfunction in pathologic conditions such as COPD. The COPD is characterized by airflow limitation that is not fully reversible and by significant systemic functional alterations of the respiratory muscles and the presence of tachypnea [15,16, 20]. In agreement, in the present study the PG showed a higher respiratory frequency (0.31 ± 0.05 Hz) than healthy subjects breathing spontaneously (0.28 ± 0.04 Hz), without statistical significance. Besides, as the PG subjects presented higher resting heart rate and spectral energy in a low frequency band when compared to CG, it is supposed that they are more prone to tachycardia than healthy subjects [16,17], representing as marker of sympathetic activity.

Former studies of HRV have shown evidence of the power spectrum band close to the respiratory frequency [1-6]. In the present study the decrease in FRF from 0.31 ± 0.06 Hz (18.6 breaths/min) or 0.28 ± 0.04 Hz (16.8 breaths/min) in spontaneous breathing to 0.11 ± 0.01 Hz (6 breaths/min) in controlled breathing, was followed by significant changes in the HRV spectral power from the HF band to the LF band. In fact, it has been reported that the decrease in respiratory frequency and increase in tidal volume are positively correlated with an increase LF band, which suggests that the respiratory parameters themselves probably cause changes in HRV parameters [21,22,23].

Brown et al. [11] showed that some HF subcomponents are synchronized with respiratory frequency and, consequently, move into the LF band. This indicates that the increase in the LF index in some mental activities [9,24] or some athletes during slow respiration can be determined from the effects of increased sympathetic nerve activity [25] as evidenced in the CGL. Besides, the magnitude of deceleration capacity (DC) was larger than the magnitude of acceleration capacity (AC) during 0.1-Hz breathing, while the difference between them reduced to near zero at higher frequencies [26].

Further, the results of our study indicate that alterations in respiratory pattern caused by low frequency respiratory should be regarded as an important confounding factor in the interpretation of HRV findings, and it is very important to assess respiratory signal before evaluating autonomic regulation of the heart using spectral HRV analysis.

4. Conclusions and Recommendations

The respiratory frequency is specific for each individual and, in many cases, LF and HF components may be totally superimposed. Therefore, we recommend that the respiratory pattern of subjects should be evaluated before spectral HRV analysis to correctly understand changes in the autonomic nervous regulation with low frequency respiration.

Acknowledgements

This work was partially supported by the Brazilian Research Council (CNPq) and CAPES Foundation.

ISSN: 2454-1907
DOI: 10.5281/zenodo.1473834

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