

Time Varying Heart Rate Variability Analysis of Active Orthostatic and Cold Face Tests Applied Both Independently and Simultaneously

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Abstract

Non-stationary heart rate variability analysis was done over a sympathetic manoeuvre, active orthostatic test (AOT) and a vagal one, cold face test (CFT), carried out either independently or simultaneously. RR interval from ECG records of 20 subjects were obtained on three conditions: AOT, CFT and simultaneous application of both stimuli (SS). HRV indexes were computed through time varying autoregressive modelling. Differences with control around intervals of interest were used for statistical comparison of manoeuvres and intervals by Friedman's test. Vagal indexes showed that CFT and SS behaved similarly ($p > 0.05$), while sympathetic indexes indicated an AOT sympathetic predominance over SS ($p < 0.05$) except for late recovery. An important change was observed in several indexes during early recovery for all conditions. This overshoot should be further explored.

1. Introduction

Active orthostatic test (AOT) causes a sympathetic response [1,2] triggered by a baroreflex response to initial blood pressure reduction, resulting in an increment on the heart rate and blood pressure [2-4]. Cold face test (CFT) produces primarily a vagal response on heart although there is a sympathetic peripheral response [5,6]. The result is reduced heart rate and peripheral vasoconstriction [5-7].

Conventional heart rate variability (HRV) analysis assumes stationarity and ergodicity [8]. However, to assess the evolution of responses to stimuli these conditions are not met. First, major transitions are present when the stimulus is applied or removed and second, it may be difficult to achieve stationarity in short term application of both AOT and CFT. To delve into the dynamics of any variable, the appropriate approach for analysis must be time-varying [9,10].

On the other hand, HRV analysis of combined stimulus and its comparison with single stimuli responses

may contribute to clarify how autonomic nervous system integrates the afferent information. Of special interest is the response of stimuli that, when applied individually, result in opposite heart rate effects as it occurs with AOT and CFT.

Thus, the aim of this paper was to analyse from a non-stationary perspective these two manoeuvres, carried out either independently or simultaneously.

2. Methods

Twenty subjects, nine women and eleven men, life-long residents of Mexico City participated in the study. Their anthropometric measurements, expressed as mean \pm standard deviation, were: height, 163.8 ± 9.1 cm and weight, 60.5 ± 11.3 Kg. Subjects were young (19 to 27 years old); healthy as established by clinical examination and electrocardiogram at rest; non-smokers, and sedentary. Their written informed consent was requested to participate. None of the subjects took any food, alcoholic or stimulant beverages, nor performed intense physical activity 12 hours before the study.

The electrocardiogram was detected through three floating electrodes, by means of bipolar lead CM5, using a bioelectric amplifier (ECG100C Biopac, USA). Electrocardiogram was acquired at 500Hz of sampling frequency (MP150 Biopac, USA).

Electrocardiogram was obtained at the same day in each subject under three different conditions: AOT, CFT and simultaneous application of both stimuli (SS). Each manoeuvre consisted on three consecutive one minute stages: control, stimulus and recovery. AOT and CFT were performed randomly, while SS was always the last manoeuvre. Five minutes were allowed between consecutive manoeuvres for recovering.

Maximum values for R waves were detected to generate temporal series of the RR intervals. Mean heart period (mean RR) was computed using a sliding window of 25 s. After detrending the time series, root mean square of successive differences (rMSSD), low frequency

component (LF), high frequency component (HF), as well as total power (TP) and LF/HF ratio [8] were estimated beat-by-beat through a time-varying autoregressive model whose parameters were estimated using RLS adaptive filtering. For each HRV index, mean control value was subtracted from the complete series to obtain the index change with respect to control.

Five intervals on interest were selected: start, course and end of the manoeuvre; early and late recovery. For each index change with respect to control, representative values for these intervals were defined as 5 s average around 65, 90, 115, 130 and 170 s, respectively. Due to a lack of normality, comparison among manoeuvres and intervals of interest were done by Friedman's test with multiple comparisons. Statistical significance was accepted at $p < 0.05$.

3. Results

Typical heart period (RR) behaviour is presented in figure 1. For AOT initial RR reduction (increment of heart rate) can be observed at the beginning of the manoeuvre. This reduction was also present in SS but apparently it occurred later. CFT produced bradycardia, observed as the RR increment. This was a gradual change reaching the maximum RR interval for the second half of the manoeuvre. The same behaviour was present for SS. In this way, AOT and CFT main described changes were obtained in the combined manoeuvre. Also, in these graphics the nonstationary behaviour of time signals can be observed, not only in the mean, but on their range of variation.

Bottom panels of figure 1 show time series examples of same subject used for HRV analysis once trend and

mean control value were removed. Changes of HRV indexes with respect to control value in the intervals of interest are shown in figure 2.

Changes in mean heart period (RR) in the intervals of interest were negative during manoeuvre and early recovery for AOT, presenting differences between consecutive intervals only for late recovery ($p < 0.05$). Contrasting, CFT RR changes were positive for all intervals but late recovery, with differences with previous interval for manoeuvre course and early recovery ($p < 0.05$). SS showed similar behaviour than CFT ($p > 0.05$).

HF and rMSSD indexes behaved in similar way for manoeuvre stage in all conditions, but changes for AOT were more apparent in rMSSD. During manoeuvre in AOT, HF and rMSSD changes were slightly negative with differences between consecutive intervals of interest for course and end of manoeuvre, respectively ($p < 0.05$), while for CFT and SS change values were positive and increased gradually without significant differences ($p > 0.05$). For early recovery, both indexes showed the highest positive value for AOT and SS. Late recovery tended to a significant reduction with respect to early recovery for CFT and SS ($p < 0.05$).

LF index in early recovery showed an important overshoot for AOT and SS ($p < 0.05$) that was also present for TP and LH/HF for AOT ($p < 0.05$).

In general, the SS indexes are closer to CFT than to AOT in all intervals of interest ($p > 0.05$) but on late recovery where CFT change values with respect to control are close to zero (practically returned to control values at this time) while SS and AOT usually remained on positive change values.

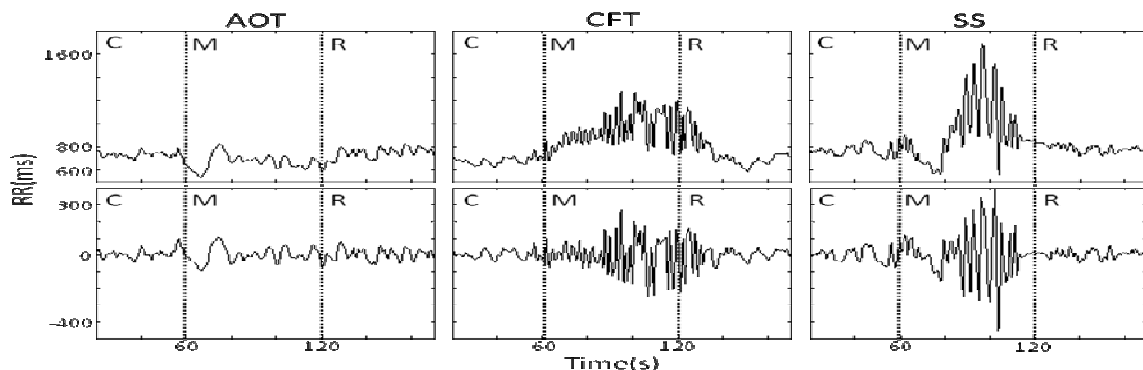


Figure 1. Typical temporal behaviour of RR time series in three studied conditions: Active orthostatic test (AOT), Cold face test (CFT) and Simultaneous stimuli (SS). Vertical dotted lines show stage changes: C control, M manoeuvre and R recovery. Top plots are original sequences while bottom ones are the result of trend and control mean removal.

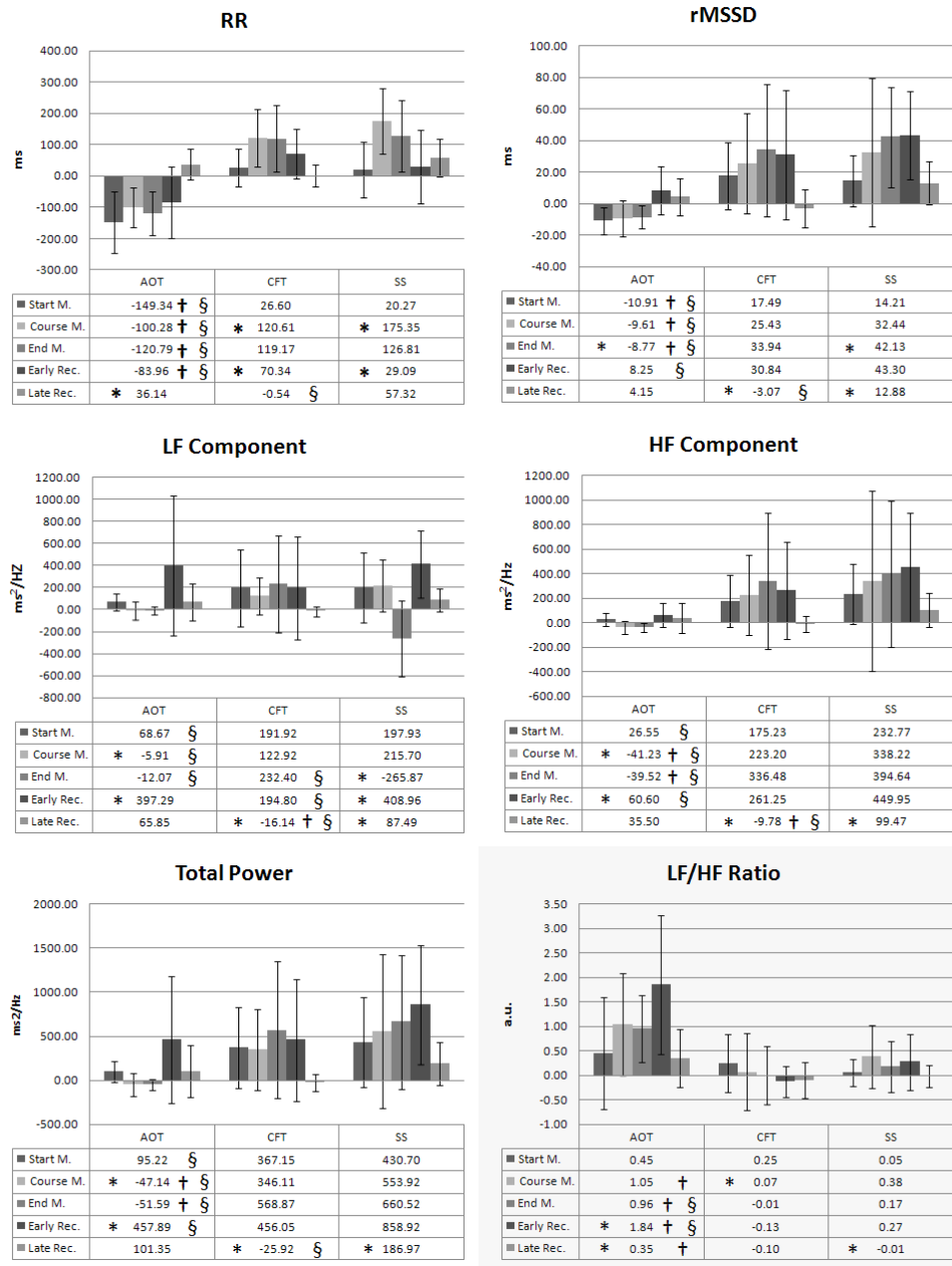


Figure 2. Mean and standard deviation of HRV indexes in intervals of interest for the three conditions: Active orthostatic test (AOT), Cold face test (CFT) and Simultaneous stimuli (SS). Start M, Course M and End M stand for start, course and end of manoeuvre, while Early Rec and Late Rec are for early and late recovery. RR: mean heart period, rMSSD: root mean square of successive RR differences, LF and HF: low and high frequency components amplitude. Friedman test for: column-wise comparison, significant differences ($p < 0.05$) between consecutive intervals of interest (*); row-wise comparison, significant differences ($p < 0.05$) between AOT or CFT with SS values (†) and AOT with CFT (§).

4. Discussion and conclusions

Main findings of the present work were: (1) Individual stimulus behaviour was mainly sympathetic for AOT and vagal for CFT as previously reported [1-7]. (2) Combined stimuli resulted in a response closer to CFT than to AOT. (3) Time-varying HRV analysis allowed studying temporal changes that occur along manoeuvre and recovery. (4) Main AOT change with respect to control was at beginning of manoeuvre. (5) CFT and SS changes during manoeuvre are gradual. (6) Early recovery showed an overshoot on AOT and SS.

In general, vagal indexes (rMSSD, HF) showed that CFT and SS behaved similarly ($p>0.05$) although SS presented values between CFT and AOT, while sympathetic indexes (LF/HF, mean RR) indicated an AOT sympathetic predominance over SS ($p<0.05$) except for late recovery.

It is relevant to notice that the use of time-varying analysis allowed assessing the manoeuvres behaviour not only once the steady state was reached, but as physiological changes occurred. In this way, as time passed during manoeuvre, gradual changes in most indexes were observed mainly for CFT and SS. Change with respect to control for most spectral indexes for AOT were positive at the beginning of manoeuvre, while they were small but negative for course and end of manoeuvre.

An important positive change was observed in several indexes during early recovery for AOT and SS. This overshoot was of large amplitude mainly for LF index. It should be further explored in future research using time-varying analysis. Manoeuvre to recovery HRV indexes changes for CFT are gradual, tending to return to control values, probably because of slow face temperature increment in contrast with fast postural change of AOT.

The response to the stimuli combination in this case was closer to CFT than SS during manoeuvre, but the early recovery overshoot observed in AOT was also present in several indexes.

The behaviour of short duration manoeuvres with substantial transients such as these studied conditions could be explored using time-varying variability indicators showing the dynamics of autonomic modulation in the course of the manoeuvres.

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