# Alteration in cardiovascular and postural control relationship in non-fainting elderly individuals

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*Abstract*— **It is known that standing induces orthostatic stress on the cardiovascular system. Our previous works have presented that the postural control during standing and cardiovascular changes are related to each other in the health young individuals. However, it remains to be checked if such a relationship is present in the elderly individuals as well. The present study conducted experiments similar to our previous studies and collected data for the muscle activation in lower leg muscles along with blood pressure during a passive stand test. Application of wavelet transform coherence method provided time frequency distribution of the coherence between the two signals. High coherence (>threshold) was observed between the two signals suggesting a strong relationship. Additionally, a frequency dependent behavior was observed between the two signals. The results from this study present strong evidence that there is a change in the relationship between the two signals with aging.**

## I. INTRODUCTION

Orthostatic challenge is the effort that the cardiovascular system invests to maintain the continuous blood flow while standing. Activation of skeletal muscles in the lower limbs (skeletal muscle pump), such as through postural shifts, walking or running, increases venous return by pumping blood accumulating in the veins back to the heart [1]. The maintenance of upright posture not only requires coordinated neuromuscular control of postural muscles [2], but also cardiovascular reflexes to maintain blood pressure (BP). The interrelationship between the two systems during standing tasks is yet to be fully understood.

Claydon and Hainsworth [3] revealed that certain individuals with orthostatic intolerance during head-up tilt test but no history of syncope or presyncope had increased postural sway in upright stance which most likely enhanced venous return preventing fainting [3]. The potential interaction between BP and postural sway has also been investigated in terms of their relationships to lower limb and trunk discomfort [4]. It remains to be checked if such a relationship exists in elderly individuals to study the possible effects of aging. Likewise, the ideal candidate for such an investigation is the individual with no history of falls or fainting due to postural hypotension. The performance in the cardio-postural investigation by the non-fainting individuals will form the baseline best case scenario and any deterioration in health will have a negative effect on the same.

Our previous work [5], [6] has already shown the existence of a bidirectional relationship between the BP changes and aggregate muscle activity during quiet standing in young healthy individuals. In this paper we investigate the presence of this relationship in the elderly individuals with no history of fainting or falling incidents. We hypothesize that: 1) there exists a strong (>threshold) relationship between the two systems in elderly non-fallers and, 2) there exists a frequency dependent activity in relationship in this age group.

We briefly explain the data acquisition and analysis methods in the section II, followed by results in section III, and discussion leading to a conclusion in section IV.

## II. METHODS

The experimental protocol was approved as minimal risk by Simon Fraser University's research ethics board. Written informed consent was obtained from each subject prior to the experiment. The subject changed into loose clothing and anthropometric data were collected. Then they proceeded for the sit-to-stand test after the instructions were provided. For the test, they were required to be seated for 5 minutes, after which they were asked to stand (assistance was provided during the transfer from sit to stand) for 5 minutes with eyes open. They were instructed to make a passive transition from the seated to upright stance phase without altering their foot position. During the test duration, they were required to maintain eye-level gaze focused to a red dot in front. The same 10-minute procedure was repeated with eyes closed. The feet were placed in a parallel foot configuration with a distance of 5 cm between the first toe and heel of each foot. The experiment was conducted in a sensory input reduced environment within an enclosed space of black drapes to remove all random visual stimuli. Apart from equipment sounds, there was no noise in the room.

### A. Participant Pool

All participants were screened for any cardiovascular disease or postural complications through verbal confirmation. All participants were required to refrain from exercise and caffeine for 24 hours prior to the experiment. The elderly individuals were screened for medical history of cardiovascular diseases, fainting incidents, orthopedic disorders, surgeries in the last 10 years to remove confounding effects in the study.

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Subject demographic and anthropometric measurements are provided in detail in table I below.

TABLE I

DEMOGRAPHIC DETAILS OF THE PARTICIPANTS.

| Group | Participant No. | Gender | Age (Years) | Height (cms) | Weight (Kg.) |
|---|---|---|---|---|---|
| Young | 10 | 5M/5F | 25.4±2.2 | 173.2±9.9 | 67.6±16.6 |
| Elderly | 10 | 3M/7F | 68.6±4.3 | 162.7±11.8 | 63.9±16.7 |

### B. Signals Acquired

Bilateral lower leg electromyography (EMG) was performed for four leg muscles: tibialis anterior, medial gastrocnemius, lateral gastrocnemius, and medial soleus. These muscles were selected based on the observations of Joseph and colleagues [7]. The sites for electrode placement were chosen in accordance with the recommendations for placement of electrodes from the SENIAM project [8]. Transdermal differential recording of signals was performed using an 8-channel EMG system, (Myosystem 1200, Noraxon Inc., Arizona, USA) and Ag/AgCl dual and single electrodes were used for signal transduction. Electrocardiography (ECG) signals were acquired (LifePak 8, Medtronic Inc, Minnesota, USA) using the Lead II configuration of ECG electrode placement. Blood pressure signals were acquired by photoplethysmography using a finger cuff electrode (Finapres, Ohmeda 2300 Ohmeda, Ohio, USA). The data were acquired using a custom data acquisition platform comprised of a 32-analog input channel DAQ card, personal computer and Labview 8.2 software (National Instruments Inc., TX, USA). A custom virtual instrument (VI) was designed using the in-built libraries and the system was configured to acquire data at 1000 Hz sampling rate and 16-bit analog-to-digital conversion.

The aggregate EMG measure for the two legs together was obtained by summing the rectified and filtered (High pass: 0.01 Hz; Low pass: 10 Hz) EMG activity from the 8 muscles. The beat-by-beat systolic blood pressure time series was obtained via the R-wave detection applied to ECG. This waveform was used in the analysis to find the relationship to aggregate EMG. The signals were resampled at 10Hz frequency prior to the subsequent WTC analysis. For this study the analysis was applied to the EMG-BP signal pair and other signals were not analyzed to retain the focus on the hypotheses.

### C. Data Analysis

Wavelet transform is a well-known method for time frequency analysis of signal spectral characteristics. The method of Wavelet Transform Coherence has been studied in detail and explained by Torrence and Compo [9] and will not be detailed here. Our prior work investigating cardio-postural interactions [5], [6] has established the threshold of significant coherence for the WTC analysis of BP-EMG signal pairs. Similar to the previous analysis we investigated the wavelet transform coherence in the low frequency (LF: 0.05-0.1 Hz; Thresh: 0.32) and very low frequency (VLF: 0.001-0.05 Hz; Thresh: 0.33) bands. The WTC analysis pipeline provides a time frequency estimate of coherence.

We obtained two aggregate measures from the time frequency distribution of the BP-EMG coherence estimate. Firstly, time points with >threshold coherence were averaged to get an average significant coherence measure for each frequency band. Lastly, the percentage time of significant coherence was obtained as the ratio of the number of time points with significant coherence with the total number of data points in a frequency band. Data for the last 4 minutes from the stand phase with eyes closed was analyzed through the analysis pipeline. This choice was based on the observation where data collected with eyes open presented with reduced sway and muscle activity.

The average metrics obtained from the data were tested for normal distribution by application of a Lilliefors test [10]. All data failed to reject the null hypothesis ("*Normal* distribution of the data") at a significance level of $p<0.05$. A standard two tailed students t-test was applied to identify the presence of statistically significant difference in the two groups for the two parameters. Additionally, we tested for the presence of frequency dependent behavior in the two variables for both the young and elderly group by statistical comparison of data in the LF and VLF bands. The null hypothesis was rejected at a significance level of $p<0.05$.

## III. RESULTS

The data were analyzed as defined in the section II above. The analyzed data for one representative elderly subject (female; age: 69 years) is presented in figure 1. The figure presents the time frequency plot of the coherence between EMG and BP signal pair (Fig. 1 (A)) and the time spread of the average band coherence in the two frequency bands (Fig. 1 B&C). The coherence threshold was maintained at 0.32 (LF band) and 0.33 (VLF band). The average value of significant coherence and percentage time of significant coherence in aggregate over the 10 subjects are presented in table II. Statistical significance was obtained for the difference in the LF and VLF bands in the elderly group for both the percentage time of significant coherence and the average significant coherence (Table II). The elderly group and the young group did not show any statistical difference for the two metrics.

TABLE II

AVERAGE SIGNIFICANT COHERENCE AND PERCENTAGE TIME OF SIGNIFICANT COHERENCE IN AGGREGATE OVER 10 SUBJECTS IN THE TWO GROUPS. DATA PRESENTED AS MEAN±S.D.

| Group | Avg. Sig. Coherence | | Percentage time Sig. Coherence | |
|---|---|---|---|---|
| | LF | VLF | LF | VLF |
| Young | 0.53 ± 0.05 | 0.56 ± 0.05 | 45.71 ± 13.61 | 53.76 ± 6.41 |
| Elderly | 0.51 ± 0.04 | 0.56 ± 0.05* | 41.78 ± 6.93 | 62.24 ± 13.57* |

* significant difference with LF ($p<0.05$)

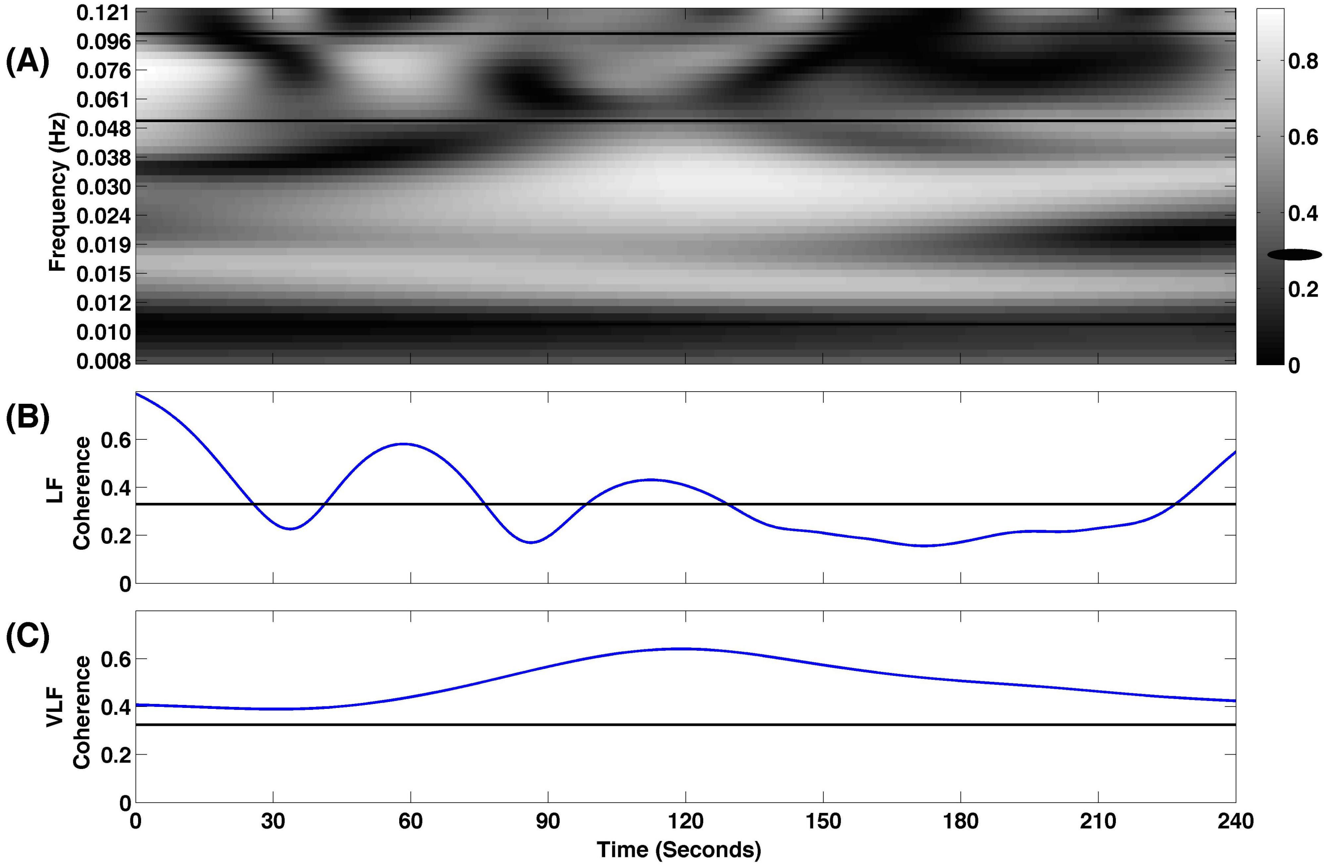


Fig. 1. Results from the analysis of data from a representative elderly subject (female,age: 67 years). (A) Time-frequency distribution of the coherence between the aggregate EMG and BP for the 4 minute duration with eyes closed and standing. Band cut-off marked as solid straight lines. A marker (black solid elipse) is placed on the colorbar for color reference of the threshold. (B) Average band coherence in the low frequency band over time. (C) Average band coherence in the very low frequency band. Thresholds presented as solid straight lines (LF: 0.32; VLF: 0.33).

## IV. DISCUSSION

Ours is the first study to investigate the cardio-postural relationship in the elderly age group (60-80 years) with no history of fainting and falls. We conducted a 10 minute passive sit-to-stand test and acquired the continuous arterial blood pressure data along with muscle activation (EMG) signals from 8 muscles primarily associated with posture control. Data were analyzed by application of wavelet transform coherence method to check for existence of relationship (coherence) (Section II). We found significant relationship (>threshold) between the EMG and BP changes in all subjects in both (young and elderly) age groups. The difference in the relationship (coherence) between the two groups did not attain statistical significance. Additionally, the coherence metrics showed frequency dependent behavior for the relationship between the two systems for the elderly group only.

We found that the elderly individuals had a significant relationship between the two systems. This was evident from the (>threshold) coherence in the two frequency bands for all subjects (Table II). On the other hand, the significant coherence and the percentage time did not show difference in the elderly group in comparison to the young age group. This suggests that the cardio-postural relationship in non-fainting elderly subjects is similar to the young healthy subjects.

Statistically significant difference ($p<0.05$) between frequency bands was observed in the elderly age group data (Table II). The average coherence and the percentage time of significant coherence were both higher in the VLF band than the LF band with statistical significance. We did not observe a similar frequency based difference in the young age group despite similar outcome in comparison to the elderly age group above. This is indicative of a shift of the cardio-postural behavior towards larger time scale (i.e. lower frequency) with aging.

The current study collected data from 10 subjects each in the two groups and was limited in statistical power to draw conclusive statistical conclusions. Further data collection with bigger cohorts and detailed analysis is required to enable the statistical inference from the data. Additionally, the current study is limited to the analysis of EMG-BP signal pair. It would be of interest to simultaneously analyze other signals to obtain a fine grain understanding of the underlying processes. Data in eyes open phase would be of importance to test for the effect of visual input on the cardio-postural interaction. The temporal behavior needs to be studied in greater detail and requires newer metrics (e.g. phase difference etc.) in addition to the coherence.

## V. CONCLUSIONS

The current paper has investigated the existence of a cardio-postural relationship in a group of elderly individuals with no history of falls or fainting. Strong relationship as >threshold coherence was observed between the two systems in the elderly group. Likewise, statistically significant frequency dependence was observed in the coherence metrics in the elderly group. The results from this study provide evidence of the existence of this relationship and a change in the behavior of this relationship with aging.

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