Heart Rate Variability Associated with Different Modes of Lower Abdominal Muscle Tension during Zen Meditation

Masaki Hoshiyama[1,2], Asagi Hoshiyama[1]

[1]Meisei University, Tokyo, Japan
[2]The University of Tokyo, Tokyo, Japan

Abstract

To understand the effect of lower abdominal muscle (LAM) tension modes on hemodynamic events elicited by deep Zen meditation during Zazen, we studied heart rate in 2 intermediate Zen meditators. The study took place over 9 sets of Zen meditations in a quiet, Zen practice hall. Each set of Zazen lasted at least for 25 minutes. The first sets were used for habituation, and the data obtained from the following eight sets were used for analysis, where 2 modes of LAM tension, i.e., intentional LAM contraction (LAMC) and LAM relaxation (LAMR), were allocated alternately. Power spectrum analysis showed distinctive change in frequency components. High frequency (HF) components increased for LAMC (p=0.05). Most notably, detrended fluctuations analysis (DFA) of HRV were around 1/2 for LAMC and 0.82 for LAMR. During Zen practice, we seat ourselves in a lotus posture with LAMC, practice lower abdominal (Tanden) breathing, and keep mind free from specific state of consciousness. We attribute the increase of HF components and decrease of DFA exponent in LAMC to the parasympathetic stimulation, and to the minimal use of antigravity muscles in the optimal posture generated by LAMC, as contrasted with the active use of antigravity muscles in the unstable posture during LAMR.

1. Introduction

Zen is a traditional meditation method which utilizes unification of body, respiration and mind [1]. Though Zen has been sophisticated highly in Japan, it is spreading widely into western world today, realizing deeper meditation with minimum body movement and distraction.

While heart rate variability (HRV) during sleep and meditation has been studied in the past [2-6], there remains a lack of consensus whether heart rate during Zen practice elicit consistent HRV differences for different modes of lower abdominal muscle (LAM) tension.

Research done in our laboratory aims at using the information contained in the fluctuation response of ECG heart rate to meditational state. To achieve this goal, it is necessary to understand better the mechanisms underlying the control of hemodynamic events through reciprocal autonomic activation elicited by meditational manipulation of body, respiration and mind. Specifically, we are interested in quantifying the degree of difference between ECG interbeat interval fluctuation responses seen during Zen meditations with different modes of LAM tension.

2. Methods

We studied heart rate in 2 intermediate Zen meditators who had been practicing multiple years of sitting Zen meditation (Zazen). The study took place over 9 sets of Zen meditations in a quiet, Zen practice hall in Kamakura or Tokyo. Each set of Zazen lasted at least for 25 minutes.

Zazen prescribes a certain bodily posture. We sit on a cushion 5 to 15 centimeters thick that is placed on our blanket. We cross our legs so that one foot rests on the opposite thigh with the sole of our foot turned up and with our knees touching the blanket (lotus or half-lotus position). The torso should be kept straight, but it should not be strained. Except in the belly, there should be no strain anywhere. The head should be kept high with our eyes opened slightly and focused on a point about a meter away on the floor (Fig 1).

We should breath calmly and deeply through nose, usually taking 2 or 3 times as long to exhale as to inhale. We should also use lower abdominal muscles (LAMC; intentional lower abdominal muscle contraction) in order to accomplish Tanden breathing.

We should keep mind free from specific state of consciousness or distractions where 3 methods have been used for over a thousand years: concentration on breathing, so called *shikantaza* which means only to sit, and the *koan*. For beginners we use the first one by counting breaths mentally from 1 to 10 beginning with 1 again (*susokukan*), or by following the breaths, being aware only of inhalation when inhaling, and only of exhalation when exhaling (*zuisokukan*).

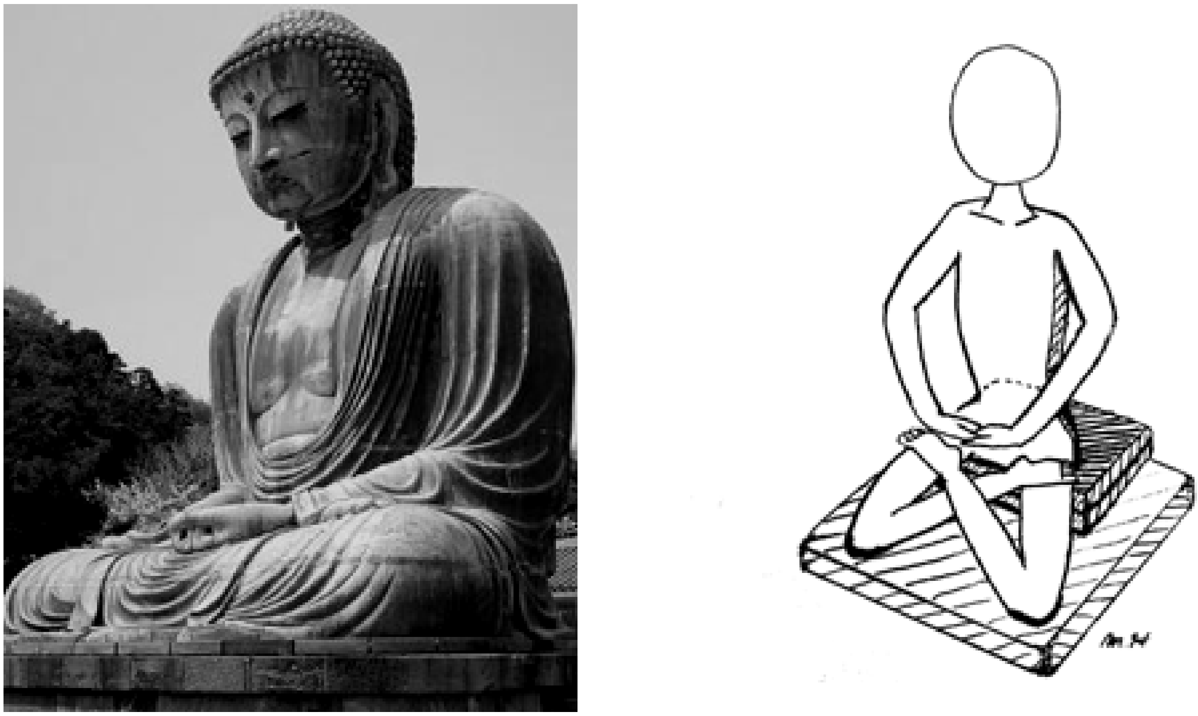

Figure 1. Bodily posture of Zazen. Left: The Great Buddha of Kamakura, Right: Schematised lotus position. See text.

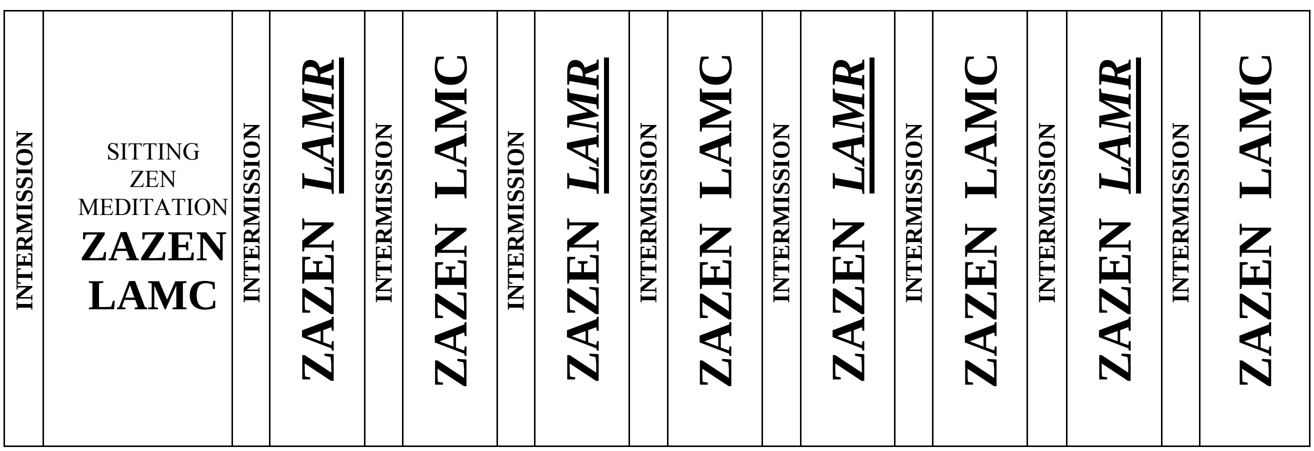

Figure 2. Sequence of events. 9 Zazen sessions were allocated with intermission before each session. The inter-beat intervals from ECG during last 8 Zazen meditations were used for analyses, where 2 modes of lower abdominal muscle tension, i.e., LAMC and LAMR, were allocated alternately. See text.

For experienced meditator we use the latter two. In *shikantaza* we directly ignore any thoughts which might arise by simply letting any thoughts in and out without sticking to them. The *koan* is logically insoluble riddle, because it contains a contradiction. Logical solutions are rejected, and experienced meditators become 'one with *koan*'.

The first sets were used for habituation, and the data obtained from the following eight sets were used for analysis. 2 modes of lower abdominal muscle tension were (LAMC; intentional lower abdominal muscle contraction) where we intentionally contract our Tanden muscles and (LAMR; intentional lower abdominal muscle relaxation) where we intentionally relax our Tanden muscles. They were allocated alternately (Fig 2). The HR was obtained from ECG recordings.

We computed the detrended fluctuations analysis (DFA) exponents [2-5] of HRV for each LAMC and LAMR tension mode during Zazen. Exponents were calculated from linear fits to log-log plots of F(n) versus n in the regime 70 < n < 350. We chose this fitting range to be above the regime of short-range correlations related to breathing and below the n values where statistical errors become too large due to the finite length of each Zazen session.

3. Results

ECG data were analyzed for 2 subjects to test for autonomic states during each set of Zen meditation.

Population averaged results for heart rate were not significantly different between each modes of LAM tension. Power spectrum analysis using Lomb method showed distinctive change in frequency components. High frequency (HF; 0.15Hz to 0.40Hz, p=0.05) components increased for LAMC. Low frequency component (LF; 0.04Hz to 0.15Hz) and very low frequency (VLF; 0.003Hz to 0.04Hz) components did not show significant differences between the 2 modes (Fig 3).

Most notably, population averaged results for DFA

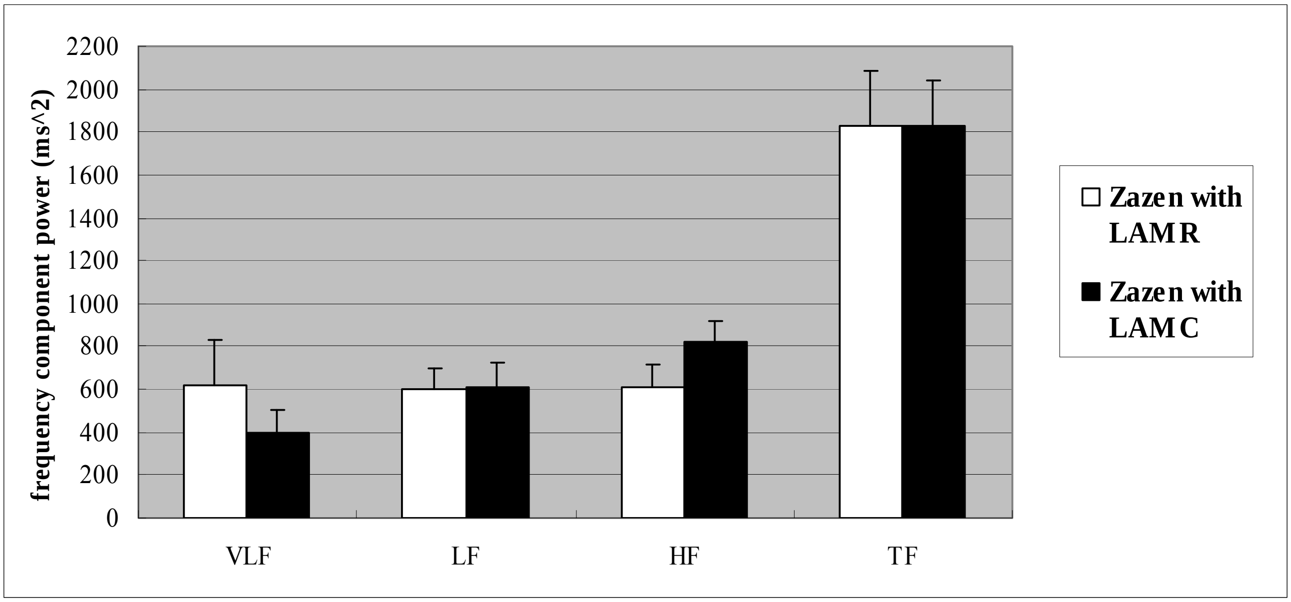

Figure 3. Frequency component power for VLF, LF, HF, TF of inter-beat intervals from ECG for Zen meditation with LAMR and LAMC. Standard errors of the mean for 8 ECG segments per each group are presented as error bars.

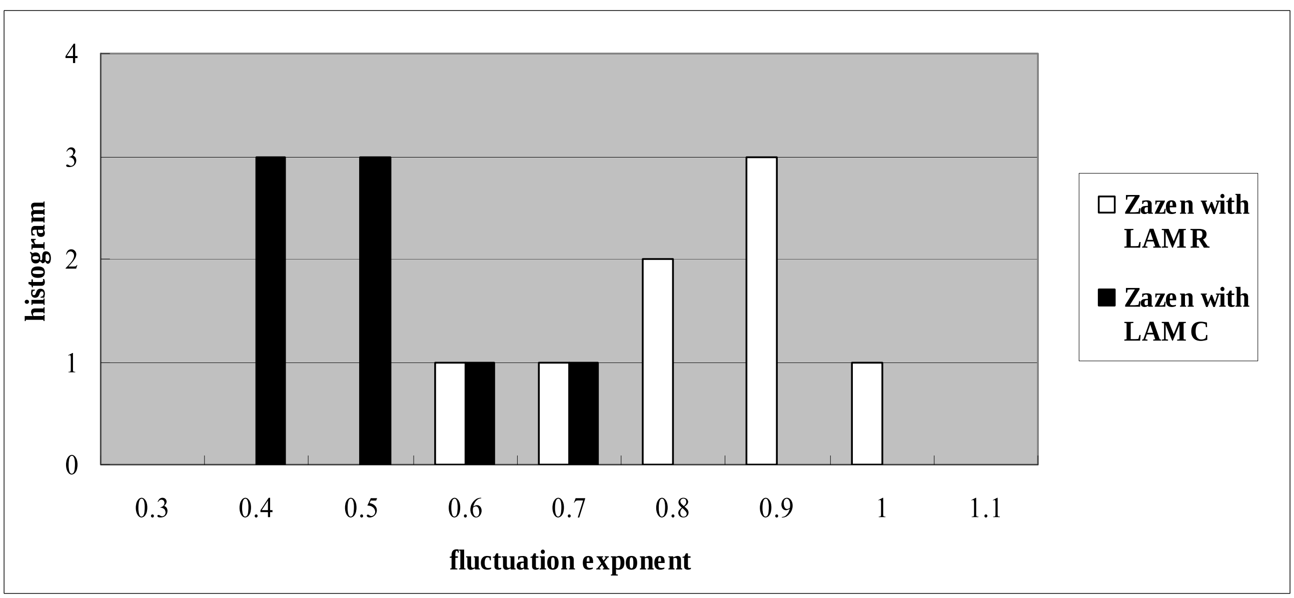

Figure 4. Histograms of DFA exponents of HRV for Zen meditation with LAMR and LAMC. DFA exponents were around 0.82 for LAMR and around 0.5 for LAMC.

exponents of HRV differed between LAMC and LAMR. The histograms were centered around 1/2 for LAMC, showing almost no correlations. DFA exponents of HRV were around 0.82 for LAMR, implicating long-range correlations (Fig. 4).

4. Discussion and conclusions

During Zen practice, we seat ourselves in a lotus posture, practice Tanden respiration, i.e., lower abdominal breathing, and keep mind free from specific state of consciousness. LAMC mode of muscle tension has been recommended in order to accomplish deep meditaional state of Zen, namely Zanmai. This study was designed to elucidate the heart rate response to muscle tension modes by comparing LAMC and LAMR during Zen meditation.

We could not find any difference in mean heart rate between LAMC and LAMR. Significant differences exist between the two groups in frequency components of the heart rate power spectrum. High frequency component is around the frequency of respiration, because it corresponds to respiratory sinus arrhythmia. Parasympathetic nervous system can transfer as high as 1Hz where respiratory sinus arrhythmia is transferred, but sympathetic nervous system cannot transfer fluctuations higher than 0.15Hz. High frequency component is modulated by parasympathetic nervous system, but not by sympathetic nervous system [7,8]. Mayer wave [9] in arterial blood pressure reflect itself to heart rate through arterial baroreflex which generates low frequency component of the heart rate variability [10,11]. Recently this low frequency component has also been found in heart rate fluctuations under the artificial heart control suggesting central origin of this autonomic nervous rhythm [12]. Since the low frequency component is within the transferable frequency of sympathetic nervous system, this component is modulated by both sympathetic and parasympathetic nervous system. As mentioned above, HF components increased for LAMC modes, which could be attributed to the less easily distracted meditation.

In the previous sleep studies, DFA exponent of HRV decreased from 0.8 to around 1/2 when they fall into light sleep from awake [13,14]. We attribute the increase of HF components and decrease of DFA exponent in LAMC to the parasympathetic stimulation, and to the minimal use of antigravity muscles in the optimal posture generated by LAMC, as contrasted with the active use of antigravity muscles in the unstable posture during LAMR, hence to the effective regulation of mind during sophisticated Zen meditation toward the edge of sleep, but not quite over it.

This result suggests the possibility of HRV as a handy and quantitative evaluator for Zen meditation.

Acknowledgements

We are grateful to Zen masters Kadowaki and Nanrei for helpful suggestions on Zen practice, meditation and enlightenment.

References

[1] Kasamatsu A, Hirai T. An electroencephalographic study on the zen meditation (Zazen). Folia Psychiatr Neurol Jpn 1966;20:315-36.

[2] Peng CK, et al. Quantification of scaling exponents and crossover phenomena in nonstationary heartbeat time series. Chaos 1995;5:82-87.

[3] Bak P, Tang C, Wiesenfeld K. Self-organized criticality. Phys Rev Lett 1987;59:381-384.

[4] Stanley HE. Introduction to Phase Transitions and Critical Phenomena. London: Oxford University Press,1971.

[5] Goldberger AL. Non-linear dynamics for clinicians: chaos theory, fractals, and complexity at the bedside. Lancet 1996;347:1312-14.

[6] Peng CK, et al. Heart rate dynamics during three forms of meditation. Int J Cardiol 2004;95:19-27.

[7] Akselrod S,Gordon D,Ubel FA,et al: Power spectrum analysis of heart rate fluctuation: A quantitative probe of beat-to-beat cardiovascular control. Science 1981;213:220-222.

[8] Pagani M, Lombardi F, Guzzetti S, et al: Power spectral analysis of heart rate and arterial pressure variabilities as a marker of sympatho-vagal interaction in man and conscious dog. Circ Res 1986;59:178-193

[9] Penaz J. Mayer waves: history and methodology. Automedica 1978;2:135-141.

[10] Madwed JB, Albrecht P, Mark RG, et al: Low-frequency oscillation in arterial pressure and heart rate: a simple computer model. Am J Physiol 1991;256:H1537-H1579.

[11] Grasso R, Schena F, Gulli G, et al. Does low-frequency variability of heart period reflect a specific parasympathetic mechanism. J Auton Nerv Syst 1997:63:30-38.

[12] Cooley RL, Montano N, Cogliati C, et al. Evidence for a central origin or the low-frequency oscillation in RR interval variability. Circulation 1998;98:556-561.

[13] Bunde A, Havlin S, Kantelhardt JW, Penzel T, Peter JH, Voigt K. Correlated and uncorrelated regions in heart-rate fluctuations during sleep. Phys Rev Lett 2000;85:3736-9.

[14] Hoshiyama M, Hoshiyama A. Heart rate variability associated with rapid eye movements during sleep. Computers in Cardiology 2007;34:689−692.

Address for correspondence.

Masaki Hoshiyama, M.D., Ph.D.
Omachi 1-9-12, Kamakura, Kanagawa, Japan
M.Hoshiyama@nifty.com