

The Impacts of Mindfulness on Heart Rate Variability: A Brief Review

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Abstract—Background: Mindfulness is a famous program that has been practiced in the world for many years, its positive functions on human well-being have been proved. Its influences on central nervous system also have been studied using electroencephalography (EEG) and functional magnetic resource image. In recent years, some studies work on its action on autonomic nervous system using Heart Rate Variability (HRV). **Objective:** The major goal of this study is to evaluate the impacts of mindfulness on HRV based on literature review. **Methods:** We search for related papers from PubMed in recent 10 years which were published in English, and examine the effectiveness of HRV on the evaluation of mindfulness. **Results:** Most of results showed that time-domain based SDNN, RMSDD and frequency-domain based HF were significantly increased after 8-week mindfulness training. **Conclusions:** HRV metrics can be useful indices for the evaluation of mindfulness studies. It proved that increased SDNN, RMSDD and HF were associated with better parasympathetic function and well-being.

Index Terms—heart rate variability, mindfulness

I. INTRODUCTION

In recent decades, mindfulness has become popular keywords related distress reduction. Mindfulness-Based Stress Reduction (MBSR) and Mindfulness-Based Cognitive Therapy (MBCT) are two famous programs which have standardized 8 weeks training course and online learning websites. Depending on them, many mindfulness programs have developed and widely used all over the world, at same time, many studies focus on Mindfulness-Based Interventions (MBIs) because of its positive effect on human health.

MBIs have been proved its positive effects in reducing stress, relieving anxiety, preventing depression and improving quality of life of healthy individuals [1], similar effects also showed in cancer patients [2]. It also works on some difficult treatment condition, such as Interstitial

Cystitis, Bladder Pain Syndrome and lower back pain etc. [3], [4].

Although many studies have positive reports for MBIs group especial when the control group is non-MBIs or usual care group, some studies report no significant difference or only short-term effect when MBIs group was compared with maintain treatment group [5], and lack of long-term positive results [6].

Because that not all studies showed the positive efficiency of MBIs, it is necessary to study physiological and biological mechanisms of mindfulness. Compared with traditional scales and questionnaires, physiological biomarkers might provide more scientific evaluations. Many medical devices, such as electroencephalography (EEG), Functional Magnetic Resource Image (fMRI) and electrocardiography (ECG) can provide physiological data for clinical disease diagnosis and evaluation, they also have been used in research for many years.

Using EEG in mindfulness studies, results show that mindfulness is associated with increased alpha and theta brain wave power [7], positive related to attentional performance and cognitive flexibility [8]. Studies with fMRI provide evidences that mindfulness practices alter intrinsic functional connectivity in brain network, might enhance self-referential processes, can reflect more consistent attention focus and awareness of sensory [9], meditation related anxiety relief is associated with special brain cortex activity [10]. All of above demonstrate the impacts of mindfulness on Central Nerve System (CNS).

Theoretically, the action of mindfulness on CNS can influence on Autonomic Nervous System (ANS). As a well-known tool for assessing ANS, heart rate variability (HRV) can be an effective tool to evaluate the impacts of mindfulness on ANS.

ECG is a recording of electrical activity of heart beats. HRV is an analysis the time differences of every R-R interval of ECG. Usually, we adopt HRV with metrics of time-domain and frequency domain to evaluate the ANS dynamic function.

Studies showed that mindfulness practices increased the High Frequency power (HF) and decreased Low Frequency power (LF) and Low Frequency to High

Frequency ratio (LF/HF) [11], and different mindfulness states may produce different HRV condition [12]. Although more and more mindfulness studies have been documented and showed the influences on HRV, there is still lack of consensus. In this study, we aimed to search for related papers and discuss consistency of results.

II. METHOD

A. Research Design

We use literature analysis and content analysis in this study. Its purpose is to collect relevant literatures about the impacts of mindfulness on HRV. We compare and generalize the literatures through content analysis.

In our study, we search literatures on PubMed, the collected papers were limited by published in English and by 10 years before April, 2018.

We use mindfulness and heart rate variability as keyword to search related papers. Those papers studying about the effects of MBIs on HRV metrics will be included.

In our study, we use frequently-used HRV metrics, such as standard deviation of all normal to normal intervals (SDNN), standard deviation of R-R interval (SDRR), standard deviation of the average of NN intervals in all 5-minute segments of the entire recording (SDANN), SDNN Index (SDNNI), NN50 count divided by the total number of all NN intervals (pNN50), and the square root of the mean of the sum of the squares of differences between adjacent NN intervals (RMSSD) as time-domain metrics, and use Total Power (TP), very low frequency power (VLF), LF, normalized LF (nLF), HF, normalized HF (nHF) and LF/HF as frequency- domain metrics.

TABLE I. STUDY CHARACTERISTICS

Study authors	Target group	Mindfulness	HRV measure	Research results about HRV after mindfulness practices
Versluis, A., et al./2018	A RCT investigated 101 participants (32 experimental, 36 control, 33 wait list)	worry-reduction EMI with mindfulness exercises 4 week	Long term HRV	Time- domain metrics: RMSSD was without significant change
Zimmermann-Schlegel, V., et al./2018	A prospective clinical trial with 113 T2DM patients	8 weeks MBSR	Short term HRV	Time- domain metrics: RMSSD was without significant change. MBSR intervention showed improved parasympathetic activities.
Park, H., et al./2018	28 female cancer patients without metastatic, pre-post comparison design	4 weeks MBSR	Short term HRV	Time- domain metrics: SDNN was increased significant. RMSSD was without significant change. The SDNN and RMSSD were lower with cancer patients than those in healthy people. Frequency- domain metrics: TP and VLF were without significant change Normalized LF was decreased significantly Normalized HF was increased significantly Improvement in HF power and decrease in anger were correlated HF was negatively correlated with depression and anxiety and positively related with well-being The LF and LF/HF ratio were positively correlated with depression and anxiety and negatively correlated with well-being. HF may be a biomarker for evaluation treatment response
Crosswell, A. D., et al./2017	71 younger breast cancer survivors. Mindfulness group(n=39) A wait-list control condition (n = 32)	6-weeks mindfulness	Short term HRV	Time- domain metrics: Control group: RMSSD increases significantly with mindfulness, while the intervention group remains the same throughout the task Intervention group: after experienced greater negative emotions, can demonstrated an efficient recovery Mindfulness training may lead to an enhanced emotional experience coupled with the ability to recovery quickly from negative emotional states
Azam, M. A., et al./2016	Total 75 undergraduate students students with tension and headaches (n = 36) students with headache-free (n = 39)	audio-guided mindfulness meditation practice or mindfulness meditation description	Short term HRV	Frequency- domain metrics HF was increased significantly from stress to mindfulness medication practice in both of two groups Better HF was shown in both group with mindfulness meditation practice as compared to mindfulness meditation description HF was significantly lower in the headache group as compared to headache-free group during the post-stress MMD condition Mindfulness promote effective recovery after a stressful event in headache group.

Owens, J. E., et al./2016	20 patients with benign palpitation MBSR group (n=10) and wait list control(n=10)	8 week MBSR	Long term HRV	Time-domain metrics: SDNN and RMSSD were without significant difference between two groups Frequency- domain metrics: HF, LF, LF/HF were without significantly difference between two groups An association between LF/HF and improvement in palpitation in MBSR group
May, R. W., et al./2016	RCT total N=124 healthy students mindfulness task group and control task group	Once, a brief 15-min mindfulness	Short term HRV	Frequency- domain metrics: There are greater reduction of nLF from baseline to intervention in mindfulness participants than in control participants.
Azam, M. A., et al./2015	Maladaptive perfectionists (n=21) and Controls (n=39)	a 10-minute audio-instructed mindfulness	Short term HRV	Frequency- domain metrics: HF decreased during stress phase in both group HF in control group was significant greater during mindfulness than during stress and rest
Nijjar, P. S., et al./2014	18 healthy volunteer	MBSR 8-week	Short term HRV	Frequency- domain metrics: HF increased after MBSR. LF decreased after complete MBSR. TP was without significant.
Evans, D.R., et al./2014	63 students to receive a cold pressor task, 26 observe group 21 describe group 39 accept group	once brief mindfulness	Short term HRV	Frequency- domain metrics: Higher HF was associated with greater pain tolerance only in control group. Unfamiliar mindfulness may not help for pain tolerate.
Howells, F.M. et al./2014	Total 21 Individuals bipolar disorder (n=12) control group(n=9)	8-week MBCT	Short term HRV	Frequency- domain metrics: Participants with bipolar disorder(BD) had increased HF peak as compared to controls before MBCT. Participants with BD showed reduced HF peak after MBCT. Emotional processing in BD is altered, and MBCT may improve emotional processing in BD
Delgado-Pastor, L.C., et al./2013	10 male experienced Vipassana meditators	practiced Vipassana meditation	Short term HRV	Frequency- domain metrics: LF/HF ratio increases during specific Vipassana. Mindfulness may change autonomic regulation.
Krygier, J. R., et al./2013	36 healthy participants	A 10-day intensive Vipassana retreat	Short term HRV	Frequency- domain metrics: HF increased overall during meditation as compared to resting baseline. LF power decrease after 10-day retreat.
Bhatnagar, R., et al./2013	Eight veterans completed the MBSR training, and 5 completed HRV measures.	8-week mindfulness, manual-based group therapy	Long term HRV	Time- domain metrics pNN50 increased after MBSR training.
Libby, D. J., et al./2012	31 community participants(after 4-week smoking cessation intervention)	practicing meditation	Short term HRV	Frequency- domain metrics: Acute increase in HF from rest to mindfulness related fewer smoke response. Change of HF may be a useful tool to predict cessation treatment response.
Prazak, M., et al./2012	506 undergraduate students	Four type mindfulness skills(observe, describe, act with awareness, Accept without Judgment)	Short term HRV	Frequency- domain metrics: VLF lower with Act and Describe skills. LF was significantly correlated Observe and Describe skills
Garland, E. L., et al./2012	53 adults (alcohol-dependent)	10 weeks of mindfulness	Short term HRV	Frequency- domain metrics: after mindfulness treatment a mean increase in HF from baseline through both stress- and alcohol cue-exposure predicted high relapse rate
Joo, H. M., et al./2010	11 patients who were suffering from spontaneous subarachnoid hemorrhage (SAH)	8 weeks MBSR	Short term HRV	Time- domain metrics: SDNN, RMSSD were significant increased after MBSR. Frequency- domain metrics: TP showed significant increase, LF,HF, LF/HF were without significant change

Note: After mindfulness intervention, improvement in psychological factors such as depression, distress, anger, insomnia, and QoL etc. all proved by scales and questionnaires analyzing.

B. Data Analysis

We search papers on PubMed using keyword mindfulness and heart rate variability, there are 59 papers in recent 10 years, and which were published in English. There were only 18 papers that were the studies focused on the HRV observations during or post mindfulness training. The articles included in this study and their findings are summarized as shown on Table I [13]-[30].

Analyzing the ECG recording, we find that researchers used long-term HRV (24-hour HRV) in 3 studies, and used short term HRV (few minutes) in other 15 papers.

For papers using long-term HRV, participants received MBIs about 4 to 8 weeks. The results showed that pNN50 was significantly increased after mindfulness [26], RMSSD, SDNN, LF and HF were without significantly change [13], [18], and there was association between LF/HF and improved disease symptom [18].

For papers using short-term HRV, participant received MBIs differently from once brief practices to 10 weeks long.

Analyzing the time-domain based HRV results, we find that SDNN and MRSSD were significantly increased after mindfulness [15], [16], [30]. Analyzing the frequency-domain based HRV results, we find that significantly increased HF [15], [17], [20]-[23], [25], [27], [29] with significant decreased LF [18], [19], [21], [25]. The results also showed that increased HF after mindfulness associated with better condition, negatively correlation with stress and disease condition. Conversely, the higher LF correlated with stress condition, negatively correlated with well-being [15], [17].

III. RESULTS

A. The Influence of Mindfulness on HRV

In Table I, we summarized the findings about the influences of mindfulness on HRV from 18 collected papers. The findings showed in Table I are just part of these papers contributions. We omitted those positive effects of mindfulness such as stress reduction, anxiety relieve, mindfulness and life quality improvement etc. proved in papers

From the Table I, we find that RMSSD and SDNN are most useful indices of time-domain, while HF is most useful indices of frequency-domain, though LF and LF/HF also been discussed. After mindfulness intervention, there are significant increase of RMSSD, SDNN and HF values in most of studies and the changes are almost consistent. LF decreased after mindfulness intervention and increased with negative condition are also proved in studies, but the change of LF/HF is uncertain.

For HRV analysis, twenty-four hours ECG recordings were only used in 3 papers; short term ECG recordings had been wildly used in more studies, it is the source of short term HRV.

SDNN is the standard deviation of NN intervals, both Sympathetic Nervous System (SNS) and Parasympathetic

Nervous System (PNS) activities can influence SDNN. In short-term HRV, lower values of SDNN can predict high morbidity and mortality, higher values of SDNN is related with better sense of well-being [31], [32].

RMSDD is root mean square of successive RR interval differences, and which is influenced by PNS and correlated with HF [33].

HF (0.15-0.40Hz) value represents the activity of parasympathetic nervous system, it highly correlated with RMSSD. It is reasonable that SDNN, RMSSD and HF have similar results in mindfulness.

In these papers, participants not only include patients but also have healthy individuals, both patient and healthy individuals have similar positive HRV change after mindfulness intervention.

Mindfulness actually can influence on ANS because of improved parasympathetic function. The change of SDNN, RMSDD and HF are similar, and are positive correlated the sense of well-being. SDNN, RMSDD and HF are useful indicators for further study on mindfulness and its action on ANS.

B. Other Findings

Not all research has positive results on HRV analysis of mindfulness, due to complex mechanism of ANS. The possible reasons may be the heterogeneities in subjects (health/patient), training period, and other possible factors.

From the findings of these articles, we found that relative healthy subgroups may gain more positive effects after mindfulness intervention as compared to people with diseases, it can be helpful to explain basic mechanism of mindfulness.

IV. DISCUSSION AND CONCLUSIONS

A. Conclusions

HRV metrics can be useful indices for mindfulness studies. The most useful HRV metrics in previous studies is including SDNN, RMSDD and HF, and all of them are important in ANS function evaluation, especially related parasympathetic nervous system. However, studies with SNS action and the balance of SNS and PNS, remain unsolved.

B. Practical Implications

In this paper, we find that SDNN, RMSDD and HF mostly been used in studies, other metrics of HRV, such as HRVTi, TINN and Poincare analysis etc. can be considered and designed into new studies, it may be helpful to explain the influence on ANS.

In prior studies, we find that different mindfulness skills or training courses may have different effect on ANS. Analyzing these difference can help us to know more about mechanisms of mindfulness and ANS.

Increased SDNN, RMSDD and HF are proved to show better parasympathetic function and we-being. At the same manner, decreased values of SDNN, RMSDD and HF are associated with higher morbidity and mortality risk [32], [34], [35].

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