A study on sound stimulation using an individual's heart rate to improve the stability and homeostasis of the autonomic nervous system: breathing support

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Abstract

Objectives: In this study, we explain the role of respiratory support by proposing aHRSR, a sound stimulation to prevent imbalance of ANS due to dynamic movement. The function and role of aHRSR was analyzed through the time and frequency domain of HRV using PPG data of 22 participants (DUIRB-202109-12). Method: Changes in the ANS were confirmed using SDNN and LF, which represent total ANS activity, and the correlation between the stimulation effect of aHRSR and respiration was analyzed using RMSSD and HF, which included parasympathetic nervous system and respiratory frequency. Results : As an effect of aHRSR on dynamic movement, the recovery time of RR interval was advanced by about 15 seconds, SDNN increased from 44.16 to 47.85 ms, and RMSSD increased from 23.73 to 31.89 ms, increasing the stability of the ANS and reducing instability. Also, by reducing the change rate of LF from -13.83 to -8.83 % and the rate of change of HF from 10.59% to 3.27%, the effect of homeostasis of the ANS according to aHRSR is also shown. In other words, aHRSR decreased HF including respiratory energy and increased RMSSD generated during stimulation of the parasympathetic nervous system. Conclusions : These results suggest that aHRSR can stimulate the parasympathetic nervous system with minimal changes in breathing by assisting breathing that occurs during dynamic movement.

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Short Title: New breath stimulation method

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Results : As an effect of aHRSR on dynamic movement, the recovery time of RR interval was advanced by about 15 seconds, SDNN increased from 44.16 to 47.85 ms, and RMSSD increased from 23.73 to 31.89 ms, increasing the stability of the ANS and reducing instability. Also, by reducing the change rate of LF from -13.83 to -8.83 % and the rate of change of HF from 10.59% to 3.27%, the effect of homeostasis of the ANS according to aHRSR is also shown. In other words, aHRSR decreased HF including respiratory energy and increased RMSSD generated during stimulation of the parasympathetic nervous system.

Conclusions : These results suggest that aHRSR can stimulate the parasympathetic nervous system with minimal changes in breathing by assisting breathing that occurs during dynamic movement.

1. Introduction

The autonomic nervous system (ANS), composed of sympathetic nervous system (SNS) and parasympathetic nervous system (PNS), is distributed in all organs in the body. The ANS plays a key role in controlling the functions of the body to cope with various internal and external environmental changes. In general, SNS is involved in emergency functions. When the body is exposed to stress, the ANS suppresses the digestive system and increases heart activity to promote energy use. PNS is involved in the protective function and act as a contrast to SNS [1, 2]. Some researchers compare the action of SNS and PNS to a seesaw. To prevent the excessive activity of one nervous system, SNS and PNS use opposing forces to intelligently control each other. In other words, both nervous system can effectively control and coordinate the function of all connected organs while maintaining in vivo homeostatic, depending on the situation [3].

A sinus node in the heart induces the heart rate through spontaneous action potential [4]. However, in the ganglion of the ANS existing around the sinus node, there are receptors that bind to acetylcholine and norepinephrine, which are neurotransmitters of the ANS, so that it is possible to control action potential of heart [5-6]. Accordingly, the heart responds sensitively to changes in the ANS and the heart rate may change depending on the ANS. For this reason, heart analysis is being used as a tool to observe changes in the ANS and this method is heart rate variability (HRV). HRV is an evaluation tool that can track the homeostasis control mechanism of the ANS in response to intrinsic and extrinsic environmental factors in real time. ANS analysis using HRV is divided into time domain and frequency domain. Time domain analysis includes the standard deviation of normal-to-normal RR intervals (SDNN) and the root mean square of continuous NN interval differences (RMSSD), which are statistics calculated from heart-beat interval differences. Frequency domain analysis computes the periodic oscillatory information of a heartbeat at various frequencies through a fast Fourier transform. Generally, it is divided into a low-frequency band of 0.05 to 0.15 Hz (LF) and a high-frequency band (HF) of 0.15 to 0.4 Hz. Since SDNN and LF are related to ANS activity, they are modulated according to changes in SNS and PNS, and RMSSD and HF are related to the activity of the vagus nerve, which belongs exclusively to the PNS [7-9].

Electrocardiogram (ECG), which can be measured in a non-invasive way, made it easy to observe clinical changes in ANS in real time through HRV analysis. HRV analysis is used to observe changes in the balance and activity of the ANS in individual conditions and diseases and to determine the effectiveness of medications and treatments [10]. As a result of these studies, deterioration of health and disease reduce the antagonistic function of SNS and PNS and finally cause imbalance of ANS. Since this imbalance adversely affects the heart, which reacts sensitively to changes in ANS, it can ultimately have fatal effects on life, such as increased arrhythmia and increased cardiovascular mortality [11-17]. To prevent and treat these risks at present, severe patients use medical devices that stimulate nervous system with electricity to activate functions and take a drug that as a nerve-blocking effect to prevent excess activity of the nervous system [18, 19].

However, the risk causing ANS imbalances not only occur in severe patients. The most common ANS imbalance in healthy individuals without disease is vasovagal syncope and orthostatic dizziness. Because cardiovascular systems are gravity-sensitive, a sudden change in body position, such as moving suddenly from sitting position to standing position, results in a momentary drop in blood pressure due to a decrease in blood flow to the heart. To protect against drop in blood pressure, the ANS immediately activates the SNS to normalize blood flow by increasing vessel constriction and the heart rate [20], but external factors such as excessive physical activity, mental stress, dehydration, and weather, can lead to abnormal feedback of the SNS, which constantly stimulates the PNS [21]. This abnormal feedback causes rapid changes in the SNS and PNS, and breaks the balance. As a result, it causes vasodilation and decreased heart rate, and reduced blood flow to the brain can cause fainting and dizziness [22–24]. These risks don't have a lethal effect on life, but depending on the circumstances that occur, the risks can become very large, and above all, there are few ways to manage and prevent the sudden ANS imbalance.

Accordingly, this study intends to propose a new method to reduce the rapid imbalance of the ANS caused by postural changes that can occur commonly in normal people in order to minimize the risks presented above, and finally suggest the role of aHRSR as respiratory support. Some studies have confirmed changes in the ANS when external sound stimulation is provided to individuals in a comfortable position [25]. However, there is little research into how external sound stimulation can affect changes in the ANS when sudden posture changes occur. Also, stimulation with vague criteria of sound will be difficult to use for treatment and prevention. To solve this problem, we developed a sound stimulation system with the same beats per minute (BPM) based on the participant's bio signal acquired through photoplethysmogram (PPG) and proposed a system that provides sound stimulation during sudden posture changes. Then, changes in the ANS due to sound stimulation were analyzed. This study clearly demonstrated the effects of sound stimulation applied to the ANS arising from dynamic movements when using personalized sound stimulation. Finally, the role and function of respiratory support of aHRSR could be confirmed. It is expected that it can be used as a breathing training method and stimulation method that continuously manages the health of the individual's ANS as a personalized health management and mobile healthcare method.

2. Materials and Methods

2.1 Average Heart Rate Sound Resonance

Resonance is a phenomenon that allows large amplitudes and energies to be transferred, even through the action of small forces at a certain frequency. The most representative theory is the Schumann resonance. The most important thing about Schumann resonance is that the electromagnetic field on earth and the physiological rhythm of the body can be synchronized [26–30]. According to another paper on synchronization, physiological rhythms are changed similar to the frequency of certain repetitive movements [31, 32], visual and sound stimulation [33, 34]. Based on this, this study suggests a hypothesis. The unique heart rate generated by the sinus node present in the heart is 100–120 beat/min, but the action of the ANS determines the average heart rate for each individual. Typically, the average heart rate with ANS applied is 60–100 beat/min for adult standard. We suggest that this is the specific resonance frequency of the individual. In other words, we hypothesized that an external stimulation with the same frequency as an individual's heart rate could induce a specific change by transmitting large energy to the ANS by synchronizing with the individual's physiological rhythm even with a small force.

In this study, sound stimulation was chosen as external stimulation with resonance frequency. The reason for this was based on the principle of brainstem auditory evoked potentials that is used as a method of examining neurological diagnosis and polyvagal theory. The sound stimulation is transmitted to the eardrum, and finally activates the brainstem to transmit auditory information [35]. The brainstem has an integrated function of cardiovascular control, breathing control, and consciousness, and plays an important role in conduction because all information relayed to the cerebral and cerebellum, or vice versa, must pass through the brainstem. In other words, activation of the brainstem using sound stimulation can affect the nervous system, and changes in ANS can be analyzed by HRV [36-38]. For this reason, it was determined that the most effective stimulation to give resonance frequency was sound stimulation (shown in Fig.1).

We measured the average heart rate of the participants to obtain a resonance frequency, and produced a 75 dB sound stimulation with the same tone frequency. The signal shape of the tone frequency follows the digital signal, and the tone duration is 0.2 seconds. The sound most similar to this type of sound stimulus is the metronome. The reason why it was developed in the above form without using the analog tone frequency is to minimize the acclimatization to sound stimuli so that continuous stimulation can be given in the experimental procedure. It was named the average heart rate sound resonance (aHRSR).

2.2. Experimental procedure

This study was conducted with the approval of Dongguk University Institutional Review Board (DUIRB-202109-12). The participants were a total of 22 people in their 20s and 30s with no history of cardiovascular diseases such as arrhythmia or myocardial infarction and of mental illness such as depression or panic disorder. The gender ratio of participants was 12 males and 10 females. The average age is 26.36 ± 3.15. People over 40 years of age were excluded from this study because they were more likely to have ANS abnormalities. All participants were informed of the purpose and methods of the study and consent was obtained prior to data measurement. Figure 2 shows the procedure for measuring ANS and HRV to confirm the effect of aHRSR. All test environments were conducted under the same conditions in an external control environment except for auditory stimulation, and aHRSR was provided through a speaker. The provided sound pro-vided a volume less than 80 dB and the speaker was placed on the right side of the participant. In order to induce and observe sufficient changes in the cardiovascular system, the sitting and standing posture were set for 5 minutes each. PPG was measured using a Biopac System M36 and SS4LA pulse sensor. For the sensor value, sampling data of 1,000 was used, and it was set to 5,000 gain, 50Hz low pass filter, and 60Hz band-stop filter, then clamped to the participant's index finger.

Phases 1 and 4 are the setup and initialization phases. Initialization is to stabilize ANS and HRV, which may have been altered by the initial movement and step 1. Phase 2 is PPG data measurement in sitting position and phase 3 shows PPG data in standing position. Each phase lasts 5 minutes. Step 1 does not provide with aHRSR in phase 3. However, in step 2, the aHRSR is provided. As a result, phases 2 and 3 show changes in ANS and HRV according to posture, and steps 1 and 2 show the effect of aHRSR applied to change ANS. Each participant had a total of 3 minutes rest while in the sitting position before experiment. In phase 1, the participant was explained with explanations and procedures for the total experiment and attached SS4LA pulse sensor. Next, participants' PPG data were acquired for 5 minutes. After 5 minutes, the participant stood up immediately, and PPG data was measured for 5 minutes while maintaining the standing position. This process is step 1 in Figure 2, and data was measured for a total of 10 minutes without aHRSR. Participants stabilize the changed ANS and HRV through a 5-minute break after step 1. The resting position was performed while sitting on a chair. Next, PPG was measured in the same way as in step 1, and the average heart rate of the PPG data of phase 2 measured in step 1 and step 2 was set as the BPM of aHRSR. Finally, in phase 3 of step 2, aHRSR was provided in line with the change in posture, and PPG data was measured for a total of 5 minutes.

2.3 Data acquisition and calculation

It is important to detect peak points in the PPG data, which indicate the maximum contraction point of the heart to obtain HRV data. We were able to obtain the RR interval data by calculating the time interval between the peaks detected through Matlab's 'findpeaks' function. RR interval data were utilized to obtain HRV, SDNN and RMSSD. In addition, the power density spectrum (PSD) of the LF and HF regions was calculated using Matlab's 'bandpower' to confirm the activity of the ANS.

First, all data was reconstructed into 5 minute segments to analyze HRV in the sitting and standing position. For the standardized data calculation, the average HRV and standard deviation of all data of the participant were calculated by posture. Then, the HRV per 5 minute was calculated for each participant and applied to the formula (Eqs. 1). To observe real-time changes, SDNN and RMSSD analyzed RR interval data to identify cardiovascular changes in the time domain (Eqs. 2, 3). Each indicator was divided into 15-second increments and divided into 20 sections in the sitting and standing posture, respectively, and a total of 40 sections. Additionally, the values were standardized to clarify the pattern of changes according to the stimulation. To observe physiological changes in the ANS, HRV per 5 minutes was transformed into the frequency domain using the Fast Fourier transform to confirm the changes of ANS. The converted HRV was divided into LF in the range of 0.04 to 0.15 Hz and HF in the range of 0.15 to 0.4 Hz using the Matlab's filter function [39, 40] and PSD for each area was calculated (Equ. 4, 5). All data were to compare the difference between the non-stimulus state and the stimulus-existing state according to the alternative hypothesis, so the aHRSR result was analyzed using a statistical method through the t-test.

2.4. Data analysis

The biosignals have deviations for each participant, and since the responses are different, normalization is necessary to eliminate the differences between the participants. Through normalization, the individual average and deviation values were removed to observe integrated changes to the stimulation. For the first time, the difference in HRV that occurs with or without aHRSR was confirmed through standardized data. In general, the ANS is controlled by electrical stimulation and drug administration. However, the above control methods rapidly change HRV, which increases the risk. So, it is carried out through a doctor's diagnosis, prescription, and surgery. However, since the aHRSR method proposed in this study aims at healthcare for health management, there should be no significant change in HRV due to aHRSR. This analysis is ultimately to confirm the possibility of inducing change using aHRSR rather than large physical stimulation as in conventional treatment methods.

Next, the effect of aHRSR on the ANS in dynamic movement was confirmed. The RR interval was analyzed to identify changes in the cardiovascular system and the ANS. As mentioned in the introduction, a sudden change in posture changes the ANS and the cardiovascular system, so it was expected that the change from a sitting posture to a standing posture would change the RR interval. After the minimum point of the RR interval that occurs in this process, the increase and change patterns of the RR interval are observed to measure the recovery time according to the abrupt change in the autonomic nervous system. In addition, since the brainstem controls the SNS and PNS of the ANS, SDNN representing the SNS and RMSSD representing PNS were analyzed in real time. Finally, the effect of aHRSR on ANS was confirmed as shown by analyzing the SNS and PNS that were changed according to the presence or absence of aHRSR. These results will confirm the ANS stability effect of aHRSR through the numerical change values of SNS and PNS. Additionally, SNS/PNS was analyzed to con-firm the balance of the ANS. Although it is important to use frequency bands LF and HF for basic analysis, SDNN/RMSSD, a useful proxy for LF/HF, was used in this study because the data used in the analysis was subdivided into 20 district data [41].

Finally, to confirm the effect of aHRSR on ANS homeostasis, the rate of change of SNS and PNS of frequency band was observed. Since the human body has a physiological rhythm such as breathing and affects the ANS, the 5-minute average LF and HF changed according to the aHRSR were confirmed through frequency domain analysis. Through this, the aHRSR role were confirmed and the correlation between the effect on the ANS and respiration was analyzed.

3 Results

3.1 Differentiation of stimulation effect

Figure 3 shows the normalized HRV of the RR interval for 5 min. In the absence of aHRSR, the average HRV of the participant according to the change in posture decreased from 0.75 ± 0.11 s to 0.65 ± 0.10 s ($P < 0.05$) and in the presence of aHRSR, it decreases from 0.76 ± 0.12 s to 0.66 ± 0.09 s ($P < 0.05$). There was a significant change according to the posture change, but there was no difference in the HRV change by aHRSR stimulation ($P > 0.05$). These results show that it doesn't cause drastic changes in the ANS, such as electrical stimulation or drug administration. In other words, it shows that the value changed depending on whether or not aHRSR was used is a feature induced according to aHRSR, not caused by a physical stimulation.

3.2. Change Stability of the autonomic nervous system

As shown in Figure 3, the change in HRV according to the aHRSR was insignificant, but the real-time RR interval, SDNN, and RMSSD show some different patterns of change. The change from the real-time RR interval to the standing posture shows a sharp decrease in the RR-interval regardless of the presence or absence of aHRSR (20 section of Fig. 4. a). However, the recovery time of the RR-interval after the maximum reduction (21 section) had a difference of about 15 seconds with 22 section in the presence of a sound stimulus and 23 section in the absence of aHRSR. That is, aHRSR induced faster heart rate recovery. In the recovery phase, SDNN and RMSSD maintain higher values during sound stimulation for sections 20 to 22 (Fig 4. b-c). Additionally, Shown in Figure 4.c, the base line of RMSSD significantly increased during sound stimulation of aHRSR (sections 24-37). These changes indicate that aHRSR stimulation not only affects the instantaneous changes in the ANS, but also continuously affects the ANS.

3.3. Balance of the autonomic nervous system

SDNN representing sympathetic nerve activity and RMSSD representing parasympathetic nerve activity were compared according to the presence or absence of sound stimulation. After standing up, the mean SDNN was 44.16 ± 13.11 ms and RMSSD 23.73 ± 9.95 ms without sound stimulation, and the mean SDNN was 47.85 ± 15.16 ms and RMSSD 31.89 ± 12.48 ms with sound stimulation. As shown in Figure 5. a-b, the mean values of SDNN and RMSSD increased, but among them, RMSSD increased significantly ($p<0.05$). Additionally, it shows that the SDNN/RMSSD (Fig. 5.c), which indicates the balance of the ANS, decreases from an average of 1.91 to 1.55 ($p<0.05$). These results show that aHRSR induces overall ANS activity, but a large portion of it induces PNS activity.

3.4. Change stability of the autonomic nervous system

Finally, the rate of change in the PSD values of frequency domain, which occurred with or without aHRSR, was analyzed. In the using aHRSR, the change rate of LF, HF, and LF/HF values decreased significantly ($0.05<P$). These results show that aHRSR reduces ANS changes and enhances stability and homeostasis (Table 1).

4. Discussion/Conclusion

The aHRSR proposed in this paper is a method intended for use by healthy individuals for prevention purposes of ANS imbalance. Therefore, aHRSR shouldn't cause catastrophic changes to the ANS. To confirm this, the following were observed in this paper for safe aHRSR stimulation. In or-der to minimize the harmful noise level, the volume does not exceed 85dB and the provision time is set to 5 minutes. The volume of aHRSR is 60 to 65 dB, similar to that of normal conversation. 75dB represents the maximum volume produced in this study. If the aHRSR set as above is similar to the electrical and chemical stimulation, and causes outlier value in the participant, there should be a change HRV according to the presence or absence of aHRSR in the results of Figure 3. However, it did not show a significant change depending on the stimulation. These results indicate that aHRSR can be safely used in daily life without causing overactivation and neuron blockage like electrical and chemical stimulation.

Next, the effect of aHRSR on dynamic movement was analyzed. aHRSR showed a fast RR interval recovery time of about 15 seconds. In other words, changes in the ANS caused by dynamic movement were quickly stabilized. Shown in Figure 4 b-c, sections 20 to 23 showed similar change patterns with and without aHRSR, but in b, SDNN maintained an uptrend during aHRSR in section 22 to 23. In this study, this cause was judged as a response to a stimulation. The moment you stand up, aHRSR induces the activity of SNS by providing a new input variable called auditory stimulus [42]. As a result, it is judged that aHRSR maintained overall ANS activity. However, the sensory adaptive system decreases its responsiveness to constant or identical stimulation [43-45]. For this reason, the sensory adaptation time of aHRSR is 45 seconds, and the PNS is activated along with the SNS as a momentary reaction, and as the SNS adapts, the PNS reaction effect seems to be continuously induced.

This study judges that aHRSR has a stabilizing effect on the ANS. The increase and decrease of SDNN and RMSSD have various patterns of change depending on lifestyle, age, and disease. As a result of analyzing SDNN and RMSSD of a total of 3,483 adults aged 18-65 in Korea, the averages were 39.6 ± 22.1 ms and 29.7 ± 18.1 ms. However, SDNN and RMSSD tend to decrease significantly when age increases, or when smoking or drinking alcohol and on the contrary, it shows a tendency to increase according to the frequency of exercise [46]. In terms of disease, it was significantly decreased in schizophrenia, bipolar disorder, and cardiovascular disease [47]. These changes increase with the stable activity and tension of the ANS [48], and decrease with the in-stability of the ANS [49]. That is, the average ms size observation of SDNN and RMSSD can confirm the stability and instability of the ANS. In this study, the change to the standing posture greatly increases the activity and tension of the ANS. Importantly, aHRSR increased the mean values of SDNN and RMSSD from 44.16 to 48.85 ms and from 23.73 to 31.89 ms. That is, these results show that aHRSR stimulation can increase the stability of the ANS and reduce the instability based on the results of previous studies.

Depending on the type of sound stimulation, various changes in the autonomic nervous system are displayed [50]. However, the aHRSR developed in this study has a greater effect on PNS. This is because aHRSR stimulation appears to stimulate the vagus nerve connected to the brainstem. The vagus nerve is an important component of the parasympathetic nerve and is involved in motor control and heart rate control. Non-invasive vagus nerve stimulation [51] exists as a technique to stimulate the vagus nerve, and its effect significantly reduced the ratio of SDNN/RMSSD and led to changes in the ANS toward the vagus nerve dominance. The results show the same pattern as in this study

Finally, in order to confirm the effect of aHRSR on the homeostasis of the ANS, the rate of change of LF and HF according to the presence or absence of aHRSR was checked. In all indicators of LF, HF, and LF/HF, the rate of change was decreased upon stimulation with aHRSR. These results indicate that stimulation of aHRSR enhances resistance to changes in the ANS. That is, it is judged to help maintain homeostasis. However, what is interesting is that the time and frequency domain indicators representing the ANS have a large correlation [52], but in this study, the activity of RMSSD and HF were different. During aHRSR, RMSSD had a larger change than before stimulation, but HF had a smaller change than before stimulation. It was determined that this cause induced physiological changes according to the stimulation of the parasympathetic nerve of the aHRSR and finally affected the breathing frequency included in the HF region [53, 54].

The effect of respiratory frequency on heart rate is called respiratory sinus arrhythmias (RSA). RSA is used to estimate vagal control of the heart and indicates an adaptive response to internal and external stimulation. An effective measure of these RSA is the RMSSD [55]. In general, breathing changes according to posture change, and the increased breathing frequency induces a rise in HF belonging to the breathing frequency range [56, 57]. Increased breathing stimulates baroreceptor reflexes present in the carotid arteries to produce RSA. Stimulation with this specific cycle affects the carotid artery and thus increases the RMSSD [58-62]. However, the aHRSR used in this study induced an increase in RMSSD when changing posture, but decreased the rate of change in HF of the participants. The aHRSR is a sound stimulation with a periodicity characterized by an individual's bpm, frequency features appear to improve ANS stability and homeostasis by stimulating baroreceptors by inducing changes in physiological characteristics other than respiration. In other words, it was confirmed that stimulation can affect the nervous system and cardiovascular system, and finally suggests that it can play a supporting role in breathing.

This study has two limitations. Although the study was conducted in controlled environments and conditions, not all ANS were controlled. The ANS connects organs and spreads throughout the body, and has both efferent and afferent neural signaling systems. Therefore, changes in the condition of other organs can cause changes in the heart. That is, even if the external environment was controlled, it was not possible to match the sleep time, food intake, smoking, age, and physical condition that could change the ANS activity in the human body. However, in this study, in order to solve this problem, the ANS that can be changed was minimized by conducting the experimental procedure within one hour per participant. The other was that the results of this study did not identify any clinical or physiological mechanisms in humans. In this study, the effect of aHRSR was established by using the existing mechanism, and then the effect of aHRSR was confirmed by analyzing the change in the HRV index obtained through the results. However, the result could only confirm the final result of the body of aHRSR stimulation, and the exact mechanism could not be secured. To secure these shortcomings, the same change pattern was found based on various existing studies, and the credibility of the aHRSR stimulation was secured by writing an interpretation and review suitable for the change.

5. Conclusion

In this study, we proposed aHRSR, a new method for improving ANS stability and homeostasis that can be used by the general public without disease. It was confirmed that aHRSR can affect the ANS at a much safer level than electrical and chemical stimulation that can cause side effects and complications. The function of aHRST induces ANS activity and increases RMSSD, an indicator of the PNS, by assisting respiration through stimulation with cycles. Through this, it is expected that this study will develop into a new technology that can prevent central nervous system diseases by suggesting a new development direction for the biofeedback method using individual biosignals.

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Statement of Ethics

Study approval statement : The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Institutional Review Board or Ethics Committee of Dongguk University Institutional Review Board (DUIRB-202109-12).

Consent to participate statement : Informed consent was obtained from all participants involved in the study.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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Author Contributions

DCK and YJL designed the experimental method to secure the composition and clinical value of this study. DKC and NHK measured the data using the designed process and method, and conducted data analysis of the participants. SMK and JYK discussed the cause and reason of the analyzed result with DCK, and finally suggested the effect and meaning of sound stimulation. SMK and JYK reviewed and edited the manuscript and approved the final version of the manuscript

Data Availability Statement

The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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Figure Legends

Fig. 1. A simplified representation of autonomic nervous system integration model and location of sound stimulation

Fig. 2. Experimental procedure. Test procedure for verifying the effects of the average heart rate sound resonance

Fig. 3. Comparison of HRV change according to Average Heart Rate Sound Resonance (aHRSR). Regardless of the presence or absence of aHRSR, the change in HRV maintains the same trend line shape. This pattern means two things. aHRSR does not induce drastic changes in HRV like chemical or electrical stimulation. Also, the effect of aHRSR was confirmed under the same conditions

Fig. 4. Real-time RR interval, the standard deviation of the NN intervals (SDNN), the square root of the mean squared differences of successive NN intervals (RMSSD) change pattern. a) shows real-time changes in the cardiovascular system, b) SDNN shows changes in the sympathetic nervous system, c) RMSSD shows changes in the parasympathetic nervous system.

Fig. 5. SDNN, RMSSD values and SDNN/RMSSD ratio in standing position with or without Average Heart Rate Sound Resonance.

Table Legends

Table. 1 Changes in LF, HF, and LF/HF values that appear when posture changes according to Average Heart

Formula

$$(X - \overline{X})/\sigma,\ \overline{X} = mean,\ \sigma = \ standard\ deviation \quad (1)$$

$$SDNN = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\mathrm{RR}_i - \mathrm{RR}_{\mathrm{mean}}\right)^2} \quad (2)$$

$$(X-\overline{X})/\sigma,\ \overline{X} = mean,\ \sigma = \ standard\ deviation\ (1)$$

$$\mathrm{RMSSD} = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n-1}\left(\mathrm{RR}_{i+1}-\mathrm{RR}_i\right)^2}\ (3)$$

$$LF(nu) = \frac{\mathrm{LF}}{LF+HF}\ (4)\ HF(nu) = \frac{\mathrm{HF}}{LF+HF}\ (5)$$

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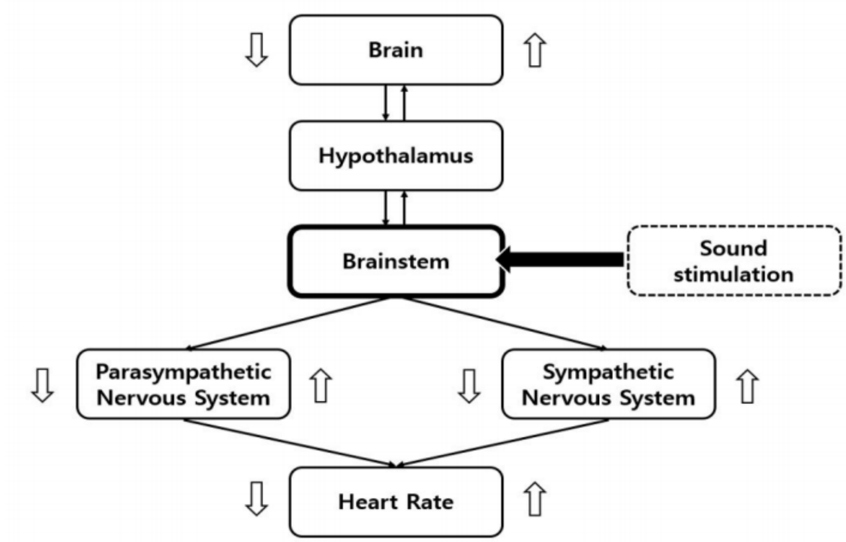
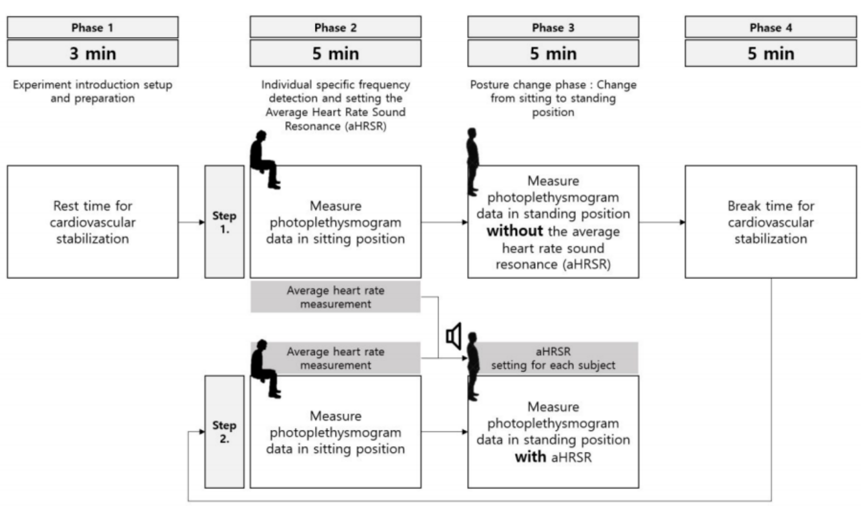
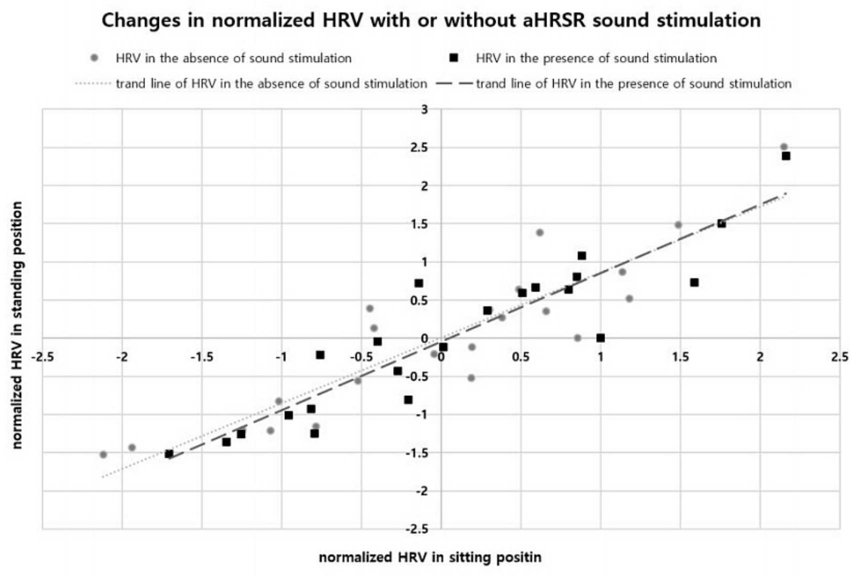
`table1.docx` available at https://authorea.com/users/625901/articles/647604-a-study-on-sound-stimulation-using-an-individual-s-heart-rate-to-improve-the-stability-and-homeostasis-of-the-autonomic-nervous-system-breathing-support






Changes in normalized HRV with or without aHRSR sound stimulation
HRV in the absence of sound stimulation
HRV in the presence of sound stimulation
trand line of HRV in the absence of sound stimulation
trand line of HRV in the presence of sound stimulation
normalized HRV in standing position
normalized HRV in sitting positin
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-2.5
-2
-1.5
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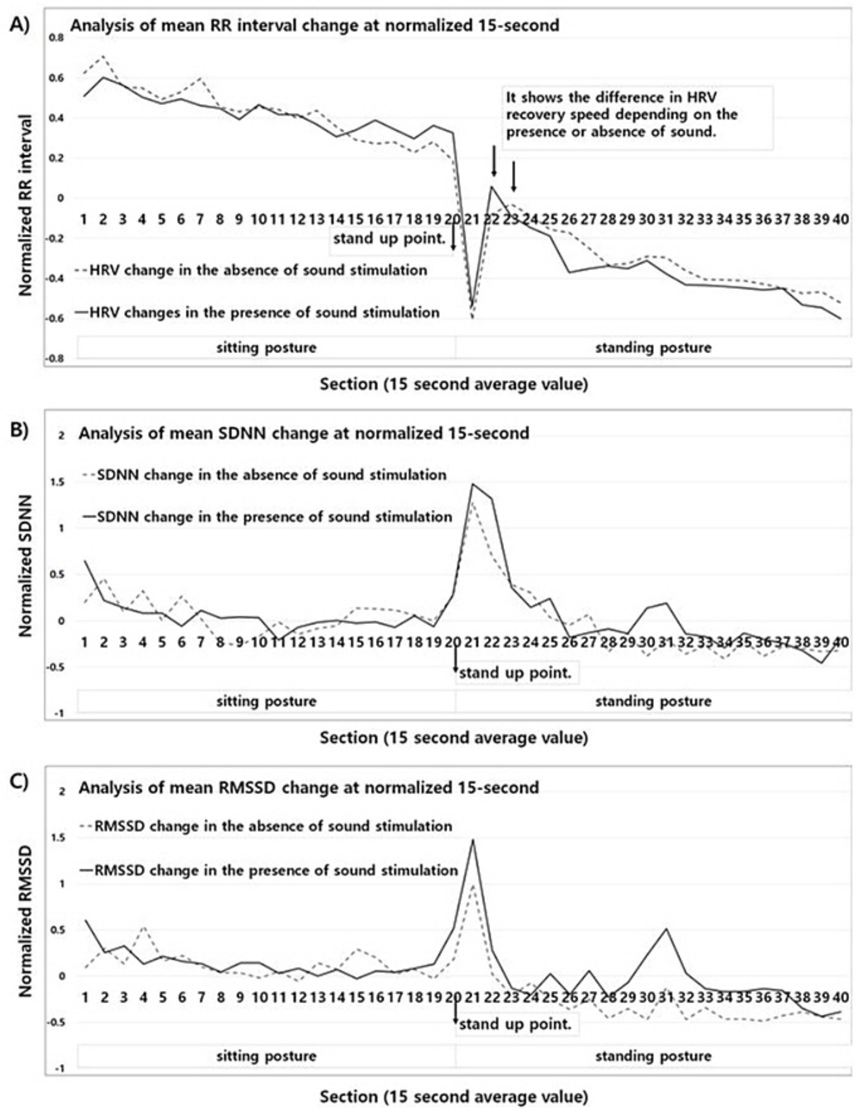
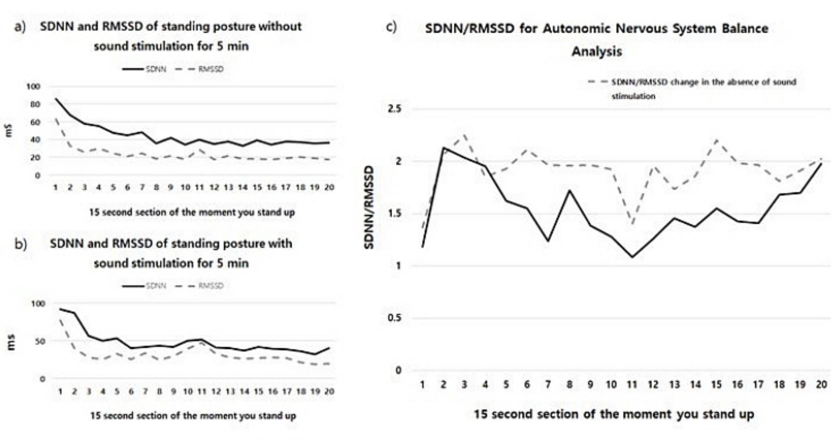
1
1.5
2
2.5


A)
Analysis of mean RR interval change at normalized 15-second
Normalized RR interval
It shows the difference in HRV recovery speed depending on the presence or absence of sound.
stand up point.
HRV change in the absence of sound stimulation
HRV changes in the presence of sound stimulation
sitting posture
standing posture
Section (15 second average value)
B)
Analysis of mean SDNN change at normalized 15-second
Normalized SDNN
SDNN change in the absence of sound stimulation
SDNN change in the presence of sound stimulation
stand up point.
sitting posture
standing posture
Section (15 second average value)
C)
Analysis of mean RMSSD change at normalized 15-second
Normalized RMSSD
RMSSD change in the absence of sound stimulation
RMSSD change in the presence of sound stimulation
stand up point.
sitting posture
standing posture
Section (15 second average value)


a) SDNN and RMSSD of standing posture without sound stimulation for 5 min
SDNN
RMSSD
15 second section of the moment you stand up
b) SDNN and RMSSD of standing posture with sound stimulation for 5 min
SDNN
RMSSD
ms
15 second section of the moment you stand up
c) SDNN/RMSSD for Autonomic Nervous System Balance Analysis
SDNN/RMSSD change in the absence of sound stimulation
SDNN/RMSSD
15 second section of the moment you stand up