Physiological Effects of Deep Touch Pressure on Anxiety Alleviation: The Weighted Blanket Approach

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Abstract

The application of deep touch pressure (DTP) has been suggested to provide positive effects on anxiety modulation. However, empirical and theoretical evidence linked to the clinical effects of DTP are relatively rare. This study conducts a quantitative analysis of behavioral assessments and performs physiological measurements, including those of electrodermal activity and heart rate variability, to understand the modulation of the autonomic nervous system (ANS), and the orchestration of sympathetic (SNS) and parasympathetic nervous systems (PsNS). The results suggest that the activation of PsNS plays a critical role in ANS modulation. This study provides physiological evidence to support the positive clinical effects of DTP for reducing anxiety in dental environments.

Keywords: Deep touch pressure (DTP), Anxiety, Heart rate variability (HRV), Electrodermal activity (EDA)

1. Introduction

Deep touch pressure (DTP) is generally referred to as a form of tactile sensory input, which is often provided by holding, stroking, hugging, swaddling, and squeezing. It can calm people who are anxious and thereby improve their coping behavior for adaptation [1-3]. The application of DTP is usually used to manage the anxiety of clients with cognitive developmental disorders, sensory modulation disorders, or psychological disorders [1,2,4]. In clinical applications, DTP intervention is a non-invasive and easily applied approach, with the client not required to have a high level of cognitive function and attention [2,3]. Therapeutic approaches related to DTP intervention modulate physiological (through proprioceptive input from the central nervous system) and psychological (calm the client) status [2]. Research has indicated that DTP intervention can increase the quality of life of patients suffering from anxiety, pain, and unrest, including individuals with developmental disability, dementia, attention deficits, and non-specific special needs [5-7].

Several devices have been designed to provide continuous DTP on the lateral and dorsal parts of the body for reducing stereotypic, self-stimulatory behavior for clinical applications [1-3]. The weighted blanket (WB) is used as a DTP intervention tool for sensory modulation. It has been increasingly employed in acute mental health care settings for crisis intervention, preparatory purposes, and as it gives subjects the feelings of safety, relaxation, and comfort [4,8]. For patients with high levels of anxiety or arousal, DTP intervention acts as a calming or focusing agent to increase activity in the parasympathetic division of the autonomic nervous system (ANS) [6]. When using a WB as a calming modality, adult subjects have demonstrated lower activity in the sympathetic division of the ANS, as reflected by electrodermal activity (EDA) [4,8]. Although a stabilizing effect was observed after the application of WB during behavioral assessments, quantitative weight of loading to the therapeutic effect is relative rare in previous studies. In addition, it is known that ANS function includes the activation of the sympathetic nervous system (SNS) in association with the relative effects of the parasympathetic nervous system (PsNS) [9]. However, few studies have used physiological variations to understand the contribution of the ANS related to anxiety performance [10]. Systematic theoretical research on the contribution of the ANS to neurobehavioral and neurophysiological effects of DTP is limited.

Heart rate variability (HRV) has been identified as a useful parameter for investigating the effect of heart rate

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response to mental stress [11]. Physiological evidence indicates that the pattern of heart rate, which oscillates around a mean value, is modulated by the ANS, reflects the continuous feedback between the central nervous system and the peripheral autonomic receptors to maintain the homeostasis of cardiovascular function [12,13,14,15]. HRV has been used as a measure of the capacity of the heart to adjust the interval between beats (R-R interval from electrocardiograms (ECGs)) when faced with distinct situations through ANS modulation [16]. The source information for HRV is a continuous beat-by-beat measurement of inter-beat intervals (IBIs). An ECG signal reflects the minute alterations in an electrical field with a fairly specific and robust waveform [13,17], and is the best way to measure IBIs. An alternative method is to use photo- plethysmograms (PPGs), obtained using a non-invasive infrared-emitting device, to detect the quantity of light passed (or reflected from) the blood flow, which produces a regular waveform of the blood volume pulse (BVP) [17,18]. PPGs can also be processed to derive pulse-by-pulse inter-pulse intervals (IPIs). Pulse rate variability (PRV) extracted from the BVP of PPGs has been studied as a potential surrogate of HRV [18]. Previous studies have demonstrated significantly high correlations ($r = 0.998$) between IBI data measured from ECGs and IPI data detected from PPGs for both stationary and non-stationary analysis [18]. Studies have also indicated that there is no significant difference between the time-domain and frequency-domain analyses of HRV derived from the R-R intervals of ECGs or pulse-pulse intervals of the BVP [17,18,20,21]. Although ECG is the gold standard for the estimation of HRV, the BVP obtained from PPGs provides valuable information for examining the responses of the autonomic cardiovascular system in applications where ECGs are not available.

Although numerous studies have been carried out on the implications and influence of DTP techniques, there is still no clear theoretical understanding for the mechanism to guide the DTP intervention. Furthermore, few studies have attempted to establish a direct relationship between DTP strategies and the physiological mechanism of anxiety management. Ethical consideration is a prerequisite for studies that involve controversial issues, such as anxiety situations [24-26]. Research on human populations should not influence any person's behavior, individual values, attitudes, and personality. It is crucial to avoid the remaining effects of stress and prevent prolonged influence when subjects are involved in an experiment with stressful situations [27]. Routine dental care is necessary for complete overall health. Although the uncomfortable feelings can be released on the end of dental procedures, persons with anxiety in dental condition are still disturbed by the condition and would significantly cause poor dental health. The present study uses dental treatment as the source of anxiety to investigate the effects of DTP provided by a WB on the ANS modulation for subjects with anxiety during dental treatment using physiological measurements and behavioral assessments. The effects of DTP intervention between dental treatment phases, with a focus on the modulation of SNS and PsNS, are also investigated.

2. Materials and methods

2.1 Apparatus for DTP

A WB is commonly used to modulate anxiety and sleep dysfunction. In order to prevent skin irritation, the WB was covered with smooth cotton fabric. The size and weight of the WB were 70 cm × 150 cm and 0.5 kg (without any weight cuff), respectively (Fig. 1). The WB provides DTP when it is assembled with a set weight cuffs, with weights of 0.5 or 1.0 kg, filled with iron pellets in an imitation leather package. Weight cuffs can be inserted into the holder on the blanket to obtain the required weight loading. Velcro was used to seal each of the openings around the edge of the blanket to prevent the weight cuffs from moving. The DTP provided by the weight loading was adjusted to be evenly distributed over the subject's body from the axillaries to the ankles. Based on previous weighted vest and WB studies, the appropriate weight loading for users is about 10% of their body weight (involved the weight of WB) [4,22,23]. An occupational therapist can then adjust the pressure according to individual requirements. The adequate weight loading of a WB was calculated using:

$$\text{Weight of WB} = \text{Subject's body weight} \times 10\% - 0.5\ \text{kg} \quad (1)$$

Based on Eq. (1), the developed WB is suitable for people whose body weight is below 95 kg. For the experiments, the DTP from the WB was adjusted as mentioned above. All subjects were administered a body weight dependent dosage of DTP to standardize treatment protocols.

2.2 Experimental design

The present study uses dental treatment as the source of anxiety to examine the effect of DTP provided by a WB during the dental treatment. The temperature of the recording environment was controlled at 21 ± 2.0 °C and the relative humidity was maintained at approximately 40~50% to prevent artifacts during data acquisition. In order to modulate the stress from the dental treatment in consistency with each other, the routine dental prophylactic appointment was used as the dental treatment procedure in this study. A dentist was instructed to provide regular uniform treatment to all subjects, including manual dental scaling and tooth cleaning with a low-speed dental handpiece and a rotary bristle brush. No local anesthetic or sedation was applied during the dental procedures.

2.3 Subjects

The quasi-experimental design of the clinical trial for repeated measures was used. A sample size of 12 was calculated based on previous studies [7,28] that showed an effect size of 0.8 with a power of 0.8 and alpha set to 0.05. The present study recruited 15 female subjects (22-33 years of age) through word-of-mouth and a sign-up poster at the Department of Dentistry, National Taiwan University Hospital. Before the testing, the experimental protocol was explained to the subjects. Informed consent was obtained prior to participation. The

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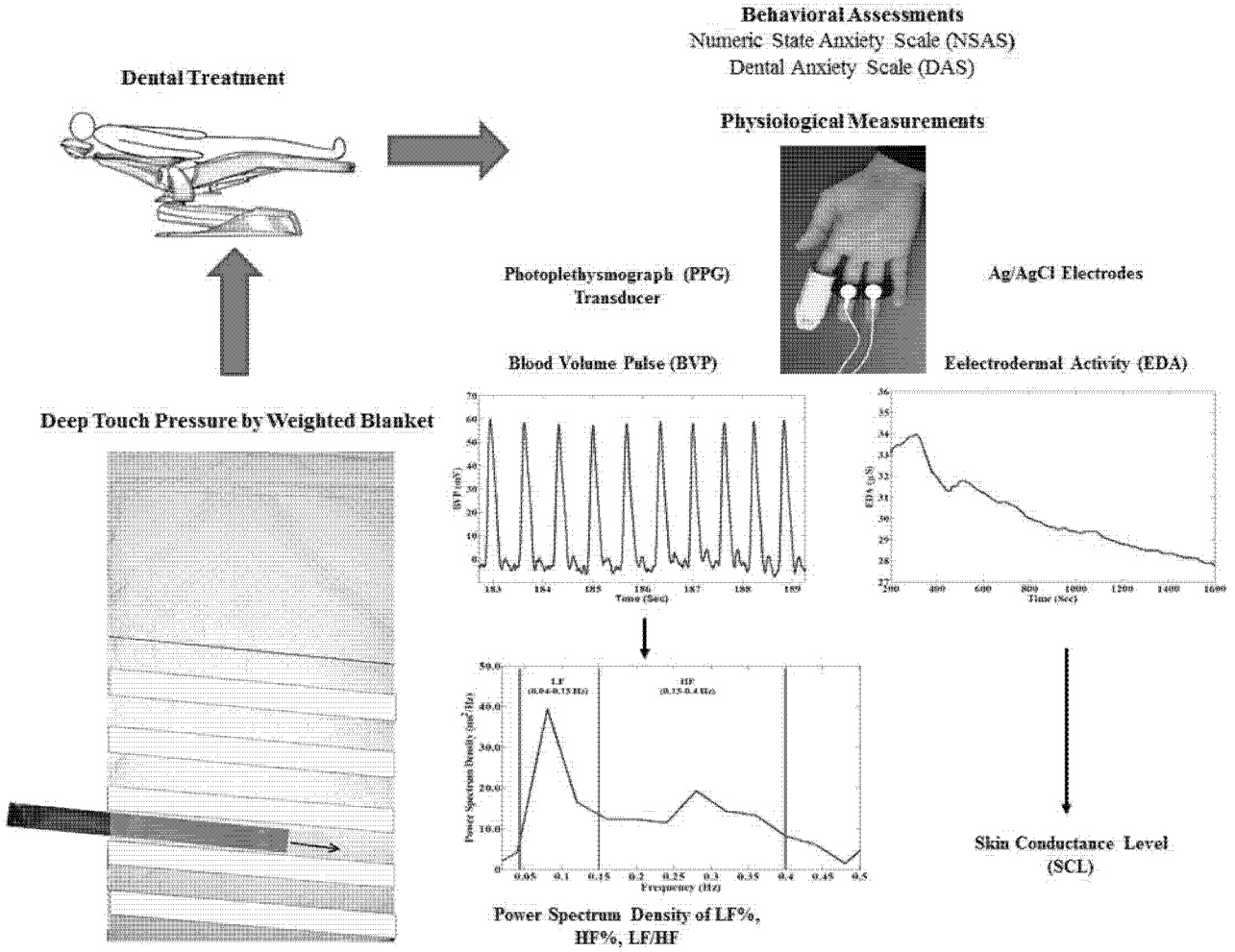


Figure 1. Experimental configuration used in the present study. The effects of DTP were measured by behavioral assessments (DAS and NSAS) and physiological measurements (EDA and BVP). The physiological signals were transformed into the parameters SCL, LF%, HF%, and LF/HF.

protocol of the study was approved by the Human Research Ethics Committee of National Taiwan University Hospital (No. 201012061RC).

The inclusion criteria were as follows: (1) able to comprehend the instructions of the testing and express his or her feelings regarding the treatment process, (2) able to participate in the dental treatment without other behavioral adaptation techniques, (3) no experience of using a WB, (4) no participation in any experimental rehabilitation or drug studies, (5) no trauma to the fingers of the left hand. The exclusion criteria were as follows: (1) the dental treatment plan requires anesthetic or sedation, (2) any medicine usage or caffeine intake on the day of treatment, (3) history of asthma, seizure, or circulation problems in the three months leading up to the experiments. Subjects with normal overnight sleep quality were recruited to prevent the effects of physiological and physical fatigue. All potential subjects received independent examinations by an occupational therapist and a dentist to determine their eligibility for inclusion. The subjects were not informed of the study hypotheses.

2.4 Physiological measurement

EDA and HRV were recorded continually throughout the testing procedures. Since EDA and HRV are sensitive indicators for ANS modulation, a standardization procedure that ensures the integrity of data was used. Figure 1 shows a flow chart of the physiological data acquisition used in the present study. A Bluetooth-based telemetry data acquisition system (Nexus-10; Mind Media B.V., Netherlands) with a 24-bit analog-to-digital converter for sampling the EDA and HRV data was used. The physiological signals were stored on a laptop computer running MS Windows. Two channels of the analog signals were collected simultaneously with carbon-coated cables and active shielding. These acquired physiological data were processed in Matlab (The Mathworks Inc., Natick, MA, USA).

Electrodermal activity: EDA is a useful indicator of reticular activities, especially emotional reactivity [9]. The method used here generally follows procedures recommended by previous studies [29-31]. Figure 1 shows the EDA recording procedure. A pair of Ag/AgCl electrodes (5 mm in diameter), fixed by a pair of 0.7 cm × 5 cm Velcro wraps, were applied to the volar surface of the middle phalanges of the long and ring fingers of the subject's left hand. Based on the tonic activity of sympathetic innervations, the skin conductivity level (SCL) which was used to reflect the raising of skin conductance was in this study [31]. A higher score of SCL indicates more SNS

activation, and thus more anxiety [4]. A high-pass filter with a cut-off frequency of 0.2 Hz was used. The sampling rate was 128 Hz.

Heart rate variability: HRV was analyzed to reflect the simultaneous effect of the SNS and the PsNS on the heart. A PPG transducer clipped to the left index finger of the subject and connected to the data acquisition system for BVP signal acquisition. The sampling rate of BVP recording was set to 128 Hz. In accordance with the guidelines of the HRV Task Force [13], several measures of HRV, mainly in the frequency domain, were computed (as shown in Fig. 2). The fast Fourier transform (FFT) was applied to BVP pulses to transform the time-domain data into three frequency bands [31] on the detrended pulse to pulse intervals (PPIs) to obtain the power spectral density (PSD) function [13].

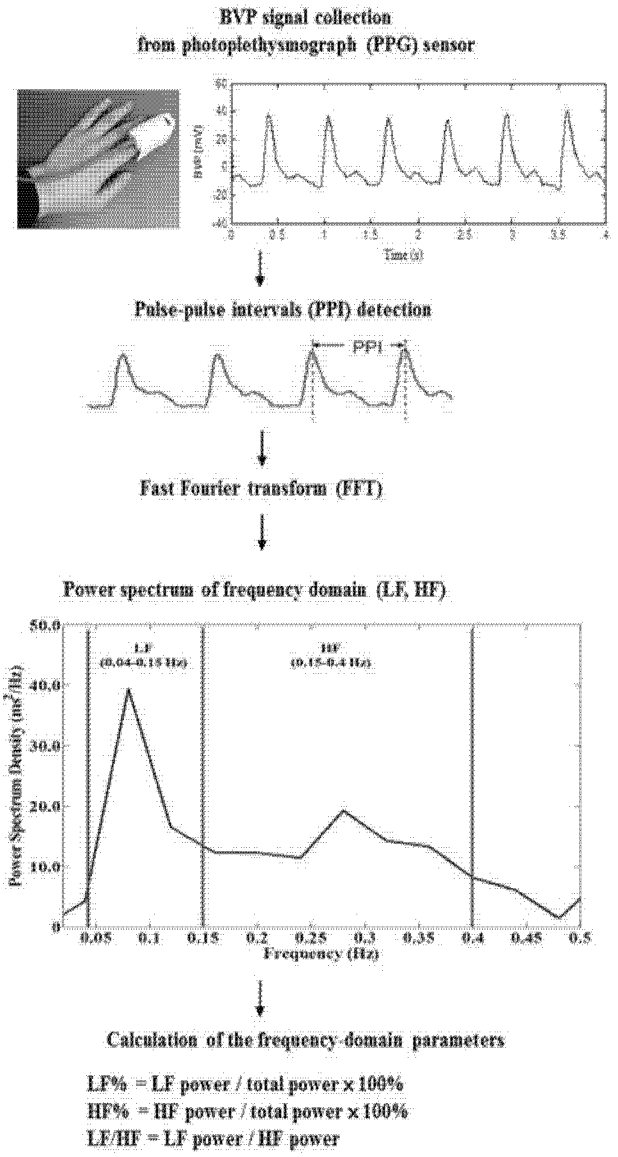


Figure 2. Analysis procedures of HRV from BVP. The BVP was recorded by a PPG sensor to detect PPIs. The power spectrum of the pulse rate in the frequency domain was calculated using FFT. The LF and HF components were analyzed.

When the PSD is calculated from a series of PPIs using one value for each beat, the frequency axis of the PSD has units of cycles per beat. The frequency axis values can be divided by the average PPI duration (expressed in seconds) to convert the units to hertz. The low-frequency (LF, 0.04-0.15 Hz) band corresponds mainly to sympathetic activity with a minor parasympathetic component, whereas the high-frequency (HF, 0.15-0.4 Hz) band is almost exclusively related to parasympathetic activity [18,33]. The units of the LF and HF power of spectrum densities are milliseconds squared (ms^2). LF% and HF% are the percentages of LF and HF in the entire spectrum, respectively, and are indicators of SNS and PsNS activity. The LF/HF ratio was calculated as a metric of sympathetic/parasympathetic balance.

LF%, HF%, and LF/HF were calculated as [13]:

$$LF\% = LF\ power/total\ power \times 100\% \quad (2)$$

$$HF\% = HF\ power/total\ power \times 100\% \quad (3)$$

$$LF/HF = LF\ power/HF\ power \quad (4)$$

The variations in HRV parameter values are related to anxiety and arousal level. The HRV parameters were analyzed from the BVP by taking the peak-to-peak distances between pulses (inter-pulse interval, IPI), which is expressed in milliseconds (ms). A BVP of 60 pulses per minute translates to an IPI of 1000 ms. In order to reject interference from BVP, the band-pass filter in the HRV analysis had a passband for IPI of 500-1500 ms, and used to remove the data if the difference greater than 25%.

2.5 Behavioral measurement

Numeric State Anxiety Scale (NSAS): In order to verify the subjective level of anxiety during DTP, subjects were asked to record their emotional status during the baseline, dental treatment stage, and post-treatment phases from 0-10 on the NSAS. NSAS is an ordinal scale, which is represented as a abscissa line to reflect the level of anxiety; 0 and 1 for none at all, 2 to 4 for a little, 5 to 7 for medium, 8 and 9 for a lot, and 10 for the worst imaginable. NSAS is easy to administer in a clinical setting to quickly quantify the levels of anxiety or modifications in anxiety, and would alleviate the insufficient realization of language in younger children. The inter-rater reliability, test-retest reliability, criterion-related validity, and concurrent validity of NSAS are adequate for clinical evaluation [34].

Dental Anxiety Scale (DAS): Corah's DAS was applied for subjects in the baseline phase. DAS is a four-item dental anxiety questionnaire with total scores that can range from 4 (not anxious at all) to 20 (extremely anxious). DAS is a convenient and quick screening tool for clinical application. If the DAS scores is higher than 12, the subjects are denoted as having a significant dental anxiety level [35,36]. A previous study indicated that DAS scores in the baseline phase are positively correlated with SCL measurements in subjects with and without dental anxiety [10].

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2.6 Procedures

The time period of testing, based on the standard dental treatment procedure, was approximately 30 to 40 minutes for each subject. Prior to testing, subjects were invited to fill out the anxiety questionnaires, namely DAS and NSAS. After the behavioral assessments, the body weights of the subjects were measured to adjust the input of the DTP provided by the WB, and it was checked whether the subjects were able to tolerate the loading. EDA and BVP measurements were performed continually with the subjects in the supine position to reduce posture effects throughout the four phases. For HRV analysis, at least 256 consecutive beats is recommend for spectral analysis. The physiological normal resting heart rate ranges from 60 to 100 beats per minute for an adult. To include a safety margin, a 5-minute sampling window (60 beats/min × 5 min = 300 beats) in each phase of this study was used, as suggested in previous studies [18].

When the testing began, the subject lay down on the dental chair for 5 minutes for a baseline measurement. The next two phases were treatment without DTP (Tx without DTP) and treatment with DTP (Tx with DTP). At the beginning of the Tx without DTP phase, the dentist used a dental handpiece to clean the subject's teeth. The dentist stopped halfway through the tooth cleaning process (after 5 to 10 minutes). The experimenter put an adjusted WB on the subject's body to begin the Tx with DTP phase. The dentist then completed the tooth cleaning process. In order to mitigate the order effects of repeated measurements, the sequence of the Tx without DTP and Tx with DTP phases was randomized using the subject's ID number. Subjects with even ID numbers underwent the Tx with DTP phase followed by the Tx without DTP phase. In the post-treatment (post-Tx) phase, the subject remained on the dental chair with WB loading for 5 minutes. At the end of testing, the subjects filled out the NSAS questionnaire.

2.7 Statistical analysis

In the descriptive statistical analysis, the demographic survey was analyzed in terms of the means and standard deviations (SD) between subjects. The one-way analysis of variance (ANOVA) was used to determine the differences among the four phases for heart rate (HR), EDA, and HRV parameters. Tukey post hoc analysis was carried out to compare the differences between phases when a significant difference was observed among the phases. All tests applied were two-tailed with a statistically significant value (α) of 0.05. Data were analyzed using SPSS 12.0 (SPSS Inc., Chicago, IL, USA).

3. Results

3.1 Demographic characteristics

The demographic characteristics of subjects are shown in Table 1. Fifteen female subjects consented to participate in the study. The mean age of the subjects was 27.00 ± 3.21 years old, with a mean body weight of 73.36 ± 15.21 kg and a mean WB weight loading of 7.10 ± 1.59 kg.

Table 1. Demographic characteristics of the subjects.

Characteristic	Value
Number of subjects	15
Gender	Female
Age (years)	27.00 (3.21)
Body weight (kg)	64.48 (17.79)
WB weight (kg)	6.24 (1.71)

The values presented in this table are mean (SD).

3.2 Analysis of behavioral assessments

All subjects (N = 15) completed the NSAS and DAS questionnaires. All subjects maintained their anxiety level under medium through the three treatment phases. At the baseline, 86.67% of subjects (N = 13) indicated a little anxiety, with the remaining 13.33% of subjects (N = 2) indicating medium anxiety about the dental treatment in the NSAS evaluation. In the Tx with DTP phase, 93.33% of subjects (N = 14) indicated that their level of anxiety is none at all, with the remaining subject having medium anxiety. In the post-treatment phase, all subjects (N = 15) felt no anxiety at all. Of the 15 subjects, 33.33% (N = 5) showed obvious dental anxiety (DAS ≧ 12), and 66.67% (N = 10) showed no anxiety (DAS < 12).

3.3 Analysis of physiological measurements

Table 2 lists the values of physiological parameters of all subjects for all phases. Significant differences between phases were observed in HR, LF%, HF%, LF/HF, normalized HR, normalized SCL, and normalized HF%. Figure 3 shows the difference in the raw data of physiological parameters between phases. No significant difference in HR was found between the

Table 2. Characteristics of the subjects for all physiological parameters for the four phases.

Parameter	N	Phase				*P*
		Baseline	Tx without DTP	Tx with DTP	Post-Tx	
		Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	
HR	15	89.53 (9.50)	83.35 (10.36)	74.40 (9.00)	76.83 (11. 05)	0.000*
normalized HR		1.00 (0.00)	0.93 (0.11)	0.84 (0.11)	0.86 (0.11)	0.000*
SCL (μS)		0.97 (0.59)	0.74 (0.50)	0.66 (0.50)	0.70 (0.57)	0.396
normalized SCL		1.00 (0.00)	0.80 (0.23)	0.73 (0.28)	0.73 (0.21)	0.004*
LF%		50.32 (12.44)	38.65 (8.63)	41.82 (10.85)	47.92 (12.85)	0.024*
normalized LF%		1.00 (0.00)	0.83 (0.35)	0.90 (0.40)	1.01 (0.36)	0.344
HF%		27.25 (14.85)	44.89 (14.59)	42.75 (14.41)	32.00 (15.03)	0.004*
normalized HF%		1.00 (0.00)	2.15 (1.44)	1.99 (1.24)	1.48 (0.99)	0.019*
LF/HF		2.61 (1.83)	1.01 (0.55)	1.13 (0.56)	2.05 (1.42)	0.002*
normalized LF/HF		1.00 (0.00)	0.60 (0.49)	0.63 (0.48)	1.11 (0.97)	0.05

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baseline and Tx without DTP phase. Significantly higher HR was observed in the baseline phase (89.53 ± 9.50 beats/min) than those for the Tx with DTP (74.40 ± 9.00 beats/min, $p = 0.001$) and post-Tx (76.83 ± 11.05, $p = 0.005$) phases, as shown in Fig. 3(a). LF% in the baseline phase (50.32 ± 12.44%) was significantly higher than that for the Tx without DTP phase (38.65 ± 8.63%, $p = 0.032$). HF% in the baseline phase (27.25 ± 14.85%) was significantly lower than those for the Tx without DTP (44.89 ± 14.59%, $p = 0.009$) and Tx with DTP (42.75 ± 14.41%, $p = 0.028$) phases. LF/HF in the baseline phase (2.61 ± 1.83) was significantly higher than those for the Tx without DTP (1.01 ± 0.55, $p = 0.004$) and Tx with DTP (1.13 ± 0.56, $p = 0.009$) phases.

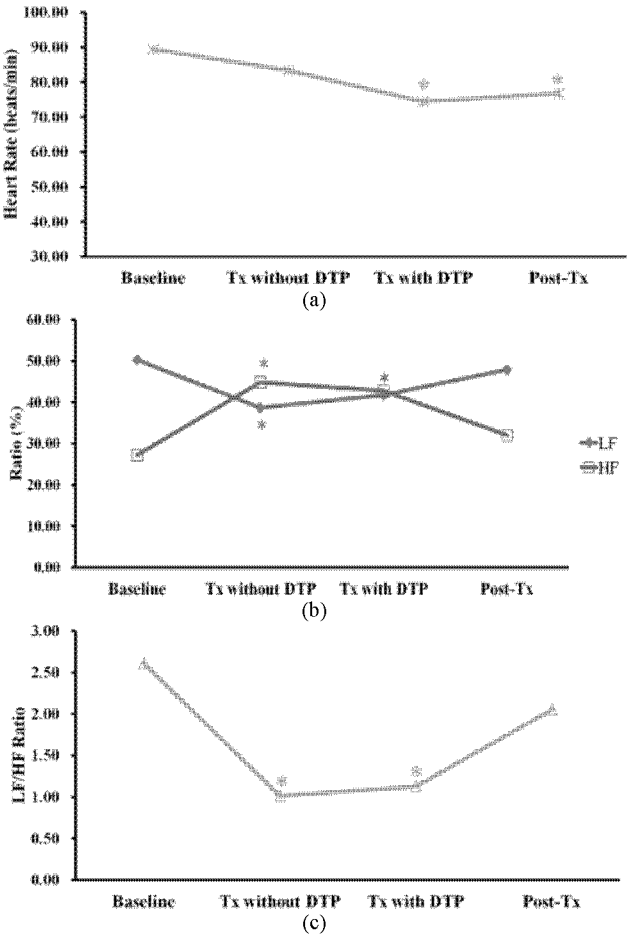


Figure 3. Physiological parameters of the subjects for the four treatment phases. (a) HR, (b) LF% and HF%, and (c) LF/HF. * indicates significant differences ($p < 0.05$) in comparison with the baseline values.

Figure 4 shows the difference in the normalized data of physiological parameters between the phases. A significantly higher normalized HR was found in the baseline phase than those for the Tx with DTP (0.84 ± 0.11, $p < 0.001$) and post-Tx (0.86 ± 0.11, $p = 0.001$) phases, as shown in Fig. 4(a). A significantly lower normalized HR was observed for the Tx with DTP phase than that for the Tx without DTP phase (0.93 ± 0.11, $p = 0.033$). Further analysis indicates that the value of normalized SCL in the baseline phase was significantly higher than those for the Tx with DTP (0.73 ± 0.28, $p = 0.009$) and post-Tx (0.73 ± 0.25, $p = 0.009$) phases, as shown in Fig. 4(a). Significant differences were observed in normalized HF%. Figure 4(b) indicates a significantly higher normalized HF% in the Tx without DTP phase (2.15 ± 1.44, $p = 0.023$). There were no significant differences between phases in normalized LF% ($p = 0.344$) and normalized LF/HF ($p = 0.05$).

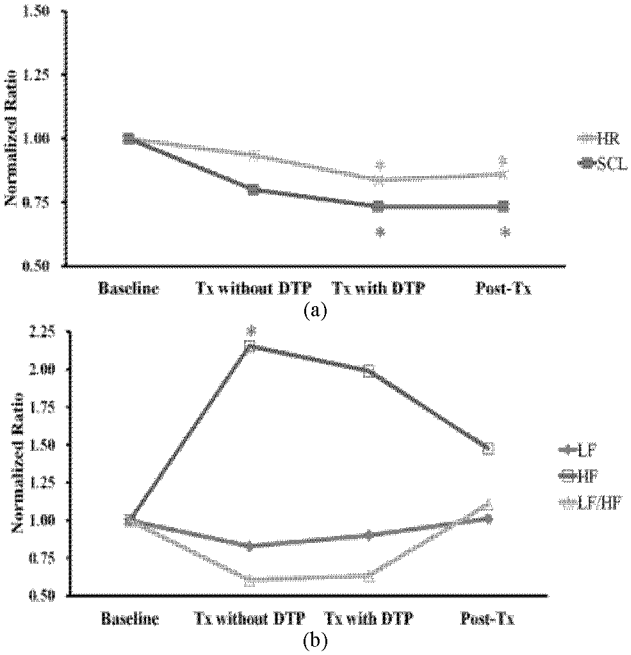


Figure 4. Normalized physiological parameters of the subjects for the four phases (a) HR and SCL, (b) LF%, HF%, and LF/HF. * indicates significant difference ($p < 0.05$) in comparison with baseline values.

4. Discussion

This study examined the effects of the WB in alleviating the anxiety of dental subjects. Based on the measurements of physiological parameters, changes in ANS modulation were used to illustrate the effects of DTP provided by a WB during dental treatment.

4.1 Physiological responses to dental treatment

Subjectively, dental treatment is a distressing event for some subjects. From the DAS and NSAS questionnaires, few subjects (13.33%) had low to medium levels of anxiety under the baseline phase. However, varying distributions of anxiety were observed from the objective physiological measurements. An increase in HR, which indicates the activation of SNS during anxiety [37], was significantly observed in the baseline condition. Although subjective behavioral measurements indicated little anxiety in the baseline phase, the results show that preparation for dental treatment and the treatment itself were stressors for the subjects. Thus, use of dental treatment as a stress condition to understand the effects of DTP.

The significant increase of SNS activation is also supported by the normalized SCL. The results indicate a much lower SNS response in the Tx without DTP phase compared to

that in the baseline phase. Physiologically, the SNS is activated to cope with adaptation to variations in the environment under stress-induced anxiety. The results in the present study indicate that the subjects triggered self-modulation to regulate the allostasis of ANS activity during the dental cleaning procedure. These results are consistent with those reported in a previous study, which found that SCL is a useful research tool for objectively quantifying anxiety [10].

The present study specifically focused on understanding the PsNS function using the parameters extracted from HRV. During the dental treatment, significantly higher normalized HF%, which indicates changes in PsNS activity, was observed in the treatment phase (Fig. 4). The present study provides information on the changes of the SNS and PsNS activities to understand the activation of ANS under anxiety conditions. Although the results are inconsistent with previous studies [10,12,38], the results show that there should be at least two ANS modulation patterns observed in healthy subjects. However, further studies are needed to verify this hypothesis. In particular, PsNS activity is necessary to illustrate the patterns of ANS modulation.

4.2 Effects of DTP during dental treatment

During dental treatment, the distribution of anxiety performance from subjective behavior assessments shifted to "none at all" in most subjects when DTP was applied. The results of behavior assessments indicate that DTP may relax subjects during dental treatment [39].

The results of physiological measurements are consistent with the results of behavioral assessments. During dental treatment, similar trend of performance was observed in both SNS-related parameters (SCL and LF%). No obvious difference was observed between Tx without DTP and Tx with DTP phases in terms of SCL ($p = 0.976$ for SCL and $p = 0.850$ for normalized SCL) and LF% ($p = 0.869$ for LF% and $p = 0.926$ for normalized LF%). Synchronized modification patterns in the PsNS changes (HF% and normalized HF%) associated with SNS reactivity were observed between the Tx without DTP and Tx with DTP phases after the start of dental treatment (Figs. 3(b) and 4(b)). During the Tx without DTP phase, higher HF% and normalized HF% indicated that the subjects might increase PsNS function by self-modulation to calm themselves. In Tx with DTP phase, the balance relationship of LF% and HF% values indicate synchronization of both in SNS and PsNS activities (Figs. 3(b) and 3(c)). This result might indicate that DTP balances ANS activity during dental treatment. Therefore, the higher PsNS activity is attributed to calming effect by both self-modulation and DTP (Fig. 4(b)).The significant difference of LF/HF ratio also indicates higher PsNS activity during treatment (both Tx without DTP and Tx with DTP phases) than that in the baseline phase. Based on the trend and performance of the HF%, it indicated that PsNS activity is evidently dominant when the stress is sustained in this study. Up to these points, it is believed that the application of the WB which provides DTP to modulate the activity of PsNS and adapt the orchestrating and organizing the balance of ANS function during the stress condition as dental treatment.

Even though the normalized LF/HF ratio showed not significant differences among the phases (Fig. 4), the relative parameters are in consistency among phases. No significant difference in the normalized LF/HF ratio might indicate the sustained balance between SNS and PsNS activations during the four phases. This result may support the notion that when subjects are in distinct experimental situations, the ANS modulates the physiological response to confront the challenges. However, further testing is needed to investigate the characteristics of normalized LF% and the normalized LF/HF ratio relative to behavioral factors. Although sympathetic activity can be determined by SCL, understanding the balance between sympathetic and parasympathetic activations is critical for detecting the function of ANS modulation during stress [40,41]. It is also believed that PsNS plays a significant role in ANS modulation and the effects of anxiety management strategies in stressful situations.

At the end of dental treatment, the subjects were relaxed due to the removal of the stressor. In this study, the subjects indicated that they were calm in the behavioral assessments, which was confirmed by the physiological measurements. In accordance with SNS and PsNS functions, lower HR and normalized SCL values (Fig. 4(a)) in associated with the sustained normalized HF% values between Tx-with DTP and Post-Tx phases supports the calming effect of DTP which is similar to the condition without medical cure. The discoveries go together the hypothesis and in accompanied with the physiological performance in Post-Tx phase. The effects of DTP induced from weight blanket on anxiety alleviating have been determinately verified in the present study. Future studies may apply DTP to children or other populations with special needs who are susceptible to anxiety during essential medical procedures.

5. Conclusion

The application of a DTP has demonstrated a potential calming effect on the alleviation of anxiety in dental environment. Our main finding is that parasympathetic activity is obviously lower in the baseline condition, and is significantly enhanced by the appropriate DTP inputs during dental condition. This promising approach demands further investigation for the mechanisms underlying the effects of DTP for advance application in dental treatments.

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