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Original Article

Effect of deep pressure input on autonomic regulation during wisdom tooth extraction: From waiting room to surgery

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Abstract *Background and purpose:* Tooth extraction is a common dental procedure associated with heightened anxiety, particularly during the waiting period before treatment. This stress response is regulated by the autonomic nervous system (ANS), comprising the sympathetic nervous system (SNS), which induces excitatory responses, and the parasympathetic nervous system (PsNS), which promotes relaxation. Deep pressure input, delivered through weighted vests and blankets, has been shown to shift ANS dominance from the SNS to the PsNS, facilitating stress reduction. This study investigated the effects of deep pressure input on ANS modulation using a weighted vest during the waiting phase and a weighted blanket during the tooth extraction phase.

Materials and methods: Healthy adults were randomly assigned to a control group or an experimental group. The control-group subjects underwent wisdom tooth extraction without deep pressure input, while the experimental-group subjects wore a weighted vest during the waiting phase and used a weighted blanket during the tooth extraction procedure. Heart rate (HR), low-frequency heart rate variability (LF-HRV), and high-frequency heart rate variability (HF-HRV) were measured to assess ANS activity.

Results: The control-group subjects exhibited increased HR, elevated LF-HRV, and reduced HF-HRV, indicating the stress-induced sympathetic activation. In contrast, the experimental-group

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subjects showed significantly lower HR and higher HF-HRV, demonstrating the enhanced parasympathetic activation that persists throughout the tooth extraction procedure.
Conclusion: Deep pressure input for high-anxiety patients can effectively reduce stress and enhances the parasympathetic activation during the wisdom tooth extraction procedure. After a large-scale clinical study, it may enter clinical application for high-anxiety patients.

Introduction

Tooth extraction is one of the most common dental surgical procedures associated with significant pain, stress, and anxiety due to the use of local anesthesia, tooth extraction instruments, and invasive preocedures.[1,2] While the surgical process itself can induce unpleasant sensory experiences[1,3,4] and hinder postoperative recovery,[5] these factors are frequently regarded as the major sources of dental anxiety.[1,2] Environmental factors, such as the waiting room experience and the amount of time spent awaiting treatment, can also contribute to anxiety.[3,4] Prolonged waiting periods may serve as a patient's first exposure to recalling threatening stimuli, exacerbating stress before dental treatment begins.[4–6] Therefore, effective reduction of stress and anxiety during the waiting period and tooth extraction procedures is crucial to minimizing risks and improving outcomes, especially for patients with high levels of anxiety or special needs.[6,7]

Deep pressure input, a form of tactile stimulation, is typically applied through firm touching, holding, stroking, hugging, swaddling, and squeezing. Various modes of deep pressure strategies, such as weighted blanket and papoose board, have been reported to alleviate anxiety during the dental procedures[8–11] and produce a calming effect.[12,13] The calming effect of deep pressure is attributed to the interaction between sensory input, cortical processing, and autonomic regulation.[8,11,14] It helps modulate the balance between the sympathetic ("fight or flight") and parasympathetic ("rest and digest") systems, shifting the body into a more relaxed state.[8,13,15,16]

Previous studies have shown that the use of a weighted deep pressure blanket during molar extraction can provide benefits similar to deep pressure massage. These include shifting the autonomic nervous system (ANS) from a sympathetic state to a parasympathetic state,[12,17] as evidenced by increased vagal tone, decreased cortisol levels, and reduced skin conductance.[12,15,18] This parasympathetic effect is associated with improved arousal modulation, characterized by a state of calmness and higher high-frequency heart rate variability (HF-HRV), a marker of inhibitory function.[11,14,19] Enhanced behavioral regulation and stress management have also been observed under these dental conditions.[9,11,14,20]

The weighted deep pressure vest, a portable and wearable device, offers an alternative means of delivering deep pressure input, particular in upright position such as sitting or standing in the waiting room. Previous studies have demonstrated its physiological effect, including the reduced sympathetic activity measured via electrodermal activity.[21] Although the weighted vest is recognized as a potentially effective tool for stress and anxiety management in the clinical, educational, and workplace environments,[21–23] its application in dental setting remains relatively unexplored.

The parasympathetic effects of deep pressure input are believed to promote calmness and arousal modulation, supporting a relatively painless dental procedure. We hypothesized that deep pressure input, applied through a weighted deep pressure vest during the waiting room condition, can serve as an effective intervention for enhancing parasympathetic responses, with effects that persist into the tooth extraction procedure. Therefore, the present study aimed to evaluate the combined effects of deep pressure input delivered through a weighted deep pressure vest in the waiting room and a weighted deep pressure blanket during the tooth extraction procedure in healthy adults. Furthermore, parasympathetic modulation patterns were investigated using HF-HRV analysis to verify the deep pressure input from the waiting phase throughout the tooth extraction procedure.

Materials and methods

Participants

Forty patients requiring wisdom tooth extraction were recruited for this single-blind, randomized, crossover controlled clinical trial conducted in the Division of Oral and Maxillofacial Surgery, Department of Dentistry, National Taiwan University Hospital (NTUH), Taiwan. The patients were excluded if they met any of the following criteria: (1) a history of systemic diseases contraindicating the surgical treatment, (2) pregnancy or lactation, (3) smoking more than 10 cigarettes per day, (4) poor overnight sleep quality, or (5) refusal to provide informed consent. All participants signed the informed consent forms, and the whole study procedures were approved by the Human Research Ethics Committee of NTUH (201012061RC).

All wisdom tooth extraction surgeries were performed under local anesthesia (4 % articaine with 1:100,000 epinephrine) by the same oral surgeon using standardized techniques and sterilized surgical instruments. A buccal mucoperiosteal flap was elevated and protected using a Minnesota retractor. Lingual flap retraction was performed only when necessary. Sterile high-speed handpieces and sterile distilled water were utilized for osteotomy and crown sectioning. Postoperatively, the wound was closed with 3—0 silk.

Deep pressure apparatus

Two types of deep pressure apparatuses were utilized in this study: (1) a weighted deep pressure vest and (2) a weighted deep pressure blanket, designed to accommodate specific postures during different phases of the study. The weighted deep pressure vest was made from smooth cotton fabric and measured 40 cm × 20 cm × 15 cm. It featured a gilet-style design with pockets for sandbags weights, applied during the waiting phase. This weighted vest provided compression and deep pressure to the wearer, delivering proprioceptive feedback to the body and shoulders by applying gravitational force through the weighted sandbags.

The weighted deep pressure blanket, also made from smooth cotton fabric to minimize discomfort (e.g., scratchy or rough, as described previously, measured 70 cm × 150 cm).[14] It was designed to be distributed weight evenly over the participant's body, from the axillary region to the ankles, using the gravity-induced force. The recommended weight for both devices was approximately 10 % of the participant's body weight.

During the study, only participants in the experimental group received deep pressure input via the weighted deep pressure vest during the waiting phase. Both the control-group and experimental-group subjects received the weighted blanket intervention during the wisdom tooth extraction procedure.

Experimental design and procedures

The measurements were conducted in the morning to minimize physiological and psychological fatigue in the participants. The recording environment was controlled at a temperature of 22 ± 3.0 °C and a relative humidity of approximately 40%—50 % to prevent artifacts in data acquisition.

Physiological data were continually recorded upon the participants' arrival at the dental clinic. Baseline measurements (T0) were collected for 5 min while participants were seated in the waiting room chair immediately after

Table 1 Characteristics and autonomic response of the subjects in both the control and experimental groups.

Characteristics and Measures	Control group	Experimental group	*P*-value
Gender (male/female)	20 (10/10)	20 (9/11)	0.761
Age (years)	28.5 ± 7.37	26.8 ± 6.17	0.432
T0			
HR (bpm)	81.60 ± 10.92	80.74 ± 14.98	0.823
LF-HRV (%)	53.21 ± 10.39	50.55 ± 12.30	0.380
HF-HRV (%)	27.76 ± 12.17	27.27 ± 12.11	0.880
LF/HF-HRV	2.42 ± 1.74	2.40 ± 1.65	0.603
Tw			
HR (bpm)	88.71 ± 9.44	75.50 ± 14.52	0.018
LF-HRV (%)	52.98 ± 9.66	43.56 ± 8.30	0.002
HF-HRV (%)	27.87 ± 10.17	45.27 ± 7.42	<0.0001
LF/HF-HRV	1.82 ± 0.57	1.00 ± 0.30	<0.0001
Tx			
HR (bpm)	89.74 ± 10.20	79.89 ± 12.65	0.011
LF-HRV (%)	52.12 ± 6.59	41.71 ± 8.61	0.001
HF-HRV (%)	37.37 ± 8.35	42.04 ± 7.25	0.152
LF/HF-HRV	1.11 ± 0.33	1.25 ± 0.56	0.188
Tx-WB			
HR (bpm)	89.52 ± 9.78	76.95 ± 12.63	0.001
LF-HRV (%)	45.19 ± 6.27	38.05 ± 7.77	0.019
HF-HRV (%)	38.88 ± 7.90	49.80 ± 8.89	<0.0001
LF/HF-HRV	1.07 ± 0.36	0.81 ± 0.24	0.220
pTx			
HR (bpm)	81.19 ± 9.33	79.43 ± 15.03	0.648
LF-HRV (%)	46.62 ± 9.46	51.19 ± 12.65	0.132
HF-HRV (%)	30.03 ± 12.52	36.55 ± 13.31	0.046
LF/HF-HRV	2.13 ± 1.44	1.66 ± 0.89	0.305

Data: mean ± SD; T0: the baseline condition; Tw: the waiting room condition; Tx: the regular tooth extraction without deep pressure input in both the experimental and control groups; Tx-WB: the regular tooth extraction with deep pressure input; pTx: the post—tooth extraction treatment condition; HR: the heart rate; LF-HRV: the percentage of the low-frequency component of heart rate variability; HF-HRV: the percentage of the high-frequency component of heart rate variability; and LF/HF-HRV: the low-frequency to high-frequency heart rate variability ratio.

check-in. The waiting phase (Tw) followed the baseline phase, representing the period between the baseline and the tooth extraction treatment. During the Tw phase, different interventions were applied to the control and experimental groups over a 5-min data acquisition period. In the control group, participants waited under the routine conditions without any additional intervention. In contrast, participants in the experimental group underwent the same waiting period but with the application of a weighted deep pressure vest, adjusted for individual load, during Tw.

The treatment phase (Tx) began after local anesthesia administration and was divided into 2 sub-phases (Tx and Tx-WB), with pauses for rest as needed. Each sub-phase involved equal duration of treatment time. In Tx, both control-group and experimental-group subjects underwent the routine wisdom tooth extraction without additional intervention. In Tx-WB, a weighted deep pressure blanket, adjusted for individual load, was applied to both groups during the tooth extraction procedure. The Tx and Tx-WB were randomized to mitigate potential order effects on the physiological measurements. The transition between Tx and Tx-WB was marked by a brief pause, as determined by the clinical requirement during the tooth extraction procedures. After the tooth extraction procedure, participants remained seated in the dental chair during the post-treatment (pTx) phase for data collection.

Heart rate variability analysis

Heart rate (HR) and HRV were measured using a photoplethysmography-based monitor connected to a Bluetooth-enabled telemetric bioamplifier (Nexus-10; Mind Media B.V., Roermond-Herten, Netherlands) with a sampling rate of 128 Hz. The data were processed using Biotrace + software for frequency domain processing.

The HRV spectrum was divided into the low-frequency (LF: 0.04—0.15 Hz) and the high-frequency (HF: 0.15—0.4 Hz) components, representing sympathetic nervous system (SNS) and parasympathetic nervous system (PsNS) activity, respectively. The LF/HF ratio was calculated as an indicator of balance between sympathetic and parasympathetic activation during the tooth extraction procedure.

Statistical analysis

The demographic data of all participants were analyzed using mean and standard deviation and presented as descriptive statistics. A two-way repeated measure ANOVA was conducted to examine the distinct phases and main effects of HRV. All statistical analyses were 2-tailed, with the significance level (α) set at 0.05. The analyses were performed using SPSS version 18.0 (SPSS Inc., Chicago, IL, USA).

Results

During the recruitment, 40 participants were randomly assigned to the experimental and control groups, with no significant differences in personal characteristics between the two groups. The demographic characteristics are

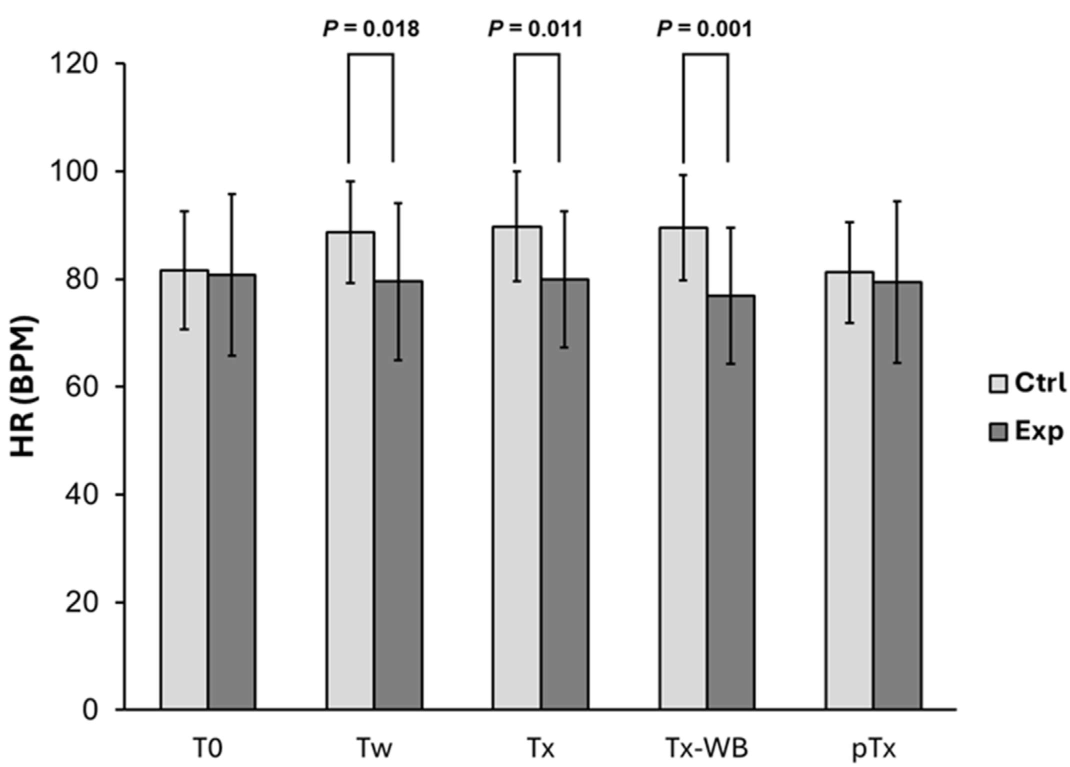

Figure 1 Comparison of heart rate (HR) between the control (Ctrl) and experimental (Exp) groups across the baseline phase (T0), the waiting phase (Tw), the treatment phase without a weighted blanket (Tx), the treatment phase with a weighted blanket (Tx-WB), and the post-treatment phase (pTx). Error bars represented the standard deviation of the mean.

presented in Table 1. Baseline measurements revealed no significant differences between the experimental and control groups.

Results from two-way repeated measure ANOVA demonstrated significant effects of HRV indices across participant groups (HR: $F(1, 190) = 15.893$, $P < 0.0001$; LF-HRV: $F(1, 190) = 6.950$, $P = 0.009$; HF-HRV: $F(1, 190) = 21.029$, $P < 0.0001$; LF/HF-HRV: $F(1, 190) = 4.129$, $P = 0.044$), phases (LF-HRV: $F(4, 190) = 8.158$, $P < 0.0001$; HF-HRV: $F(4, 190) = 12.536$, $P < 0.0001$; LF/HF-HRV: $F(4, 190) = 13.724$, $P < 0.0001$), and the phase—subject interactions (LF-HRV: $F(4, 190) = 3.226$, $P = 0.014$; HF-HRV: $F(4, 190) = 5.833$, $P < 0.0001$).

For the HR, intergroup analysis revealed participants in the control group exhibited higher HR during the Tw, Tx, and Tx-WB phases compared to those in the experimental group. However, no significant differences were observed during the baseline (T0) and the post-treatment (pTx) phases, as shown in Table 1. Intragroup analysis indicated no significant HR differences across all phases in both two groups, as illustrated in Fig. 1. The application of deep pressure input during the waiting phase was associated with lower HR during the subsequent tooth extraction phases, regardless of the presence of further deep pressure input.

For LF-HRV, intragroup data of the control group showed no significant differences across the intervention phases, suggesting sustained sympathetic activity throughout. In contrast, the experimental-group subjects displayed significantly lower LF-HRV during the Tx phase compared to T0 ($P = 0.039$) and pTx ($P = 0.020$), as shown in Fig. 2. Intergroup analysis demonstrated higher LF-HRV in the Tw, Tx, and Tx-WB phases in the control-group subjects compared to the experimental-group subjects (Table 1). These findings suggest that deep pressure input reduces the sympathetic activity during the wisdom tooth extraction phases in the experimental-group subjects.

For HF-HRV, significant intra- and intergroup differences were observed, as shown in Fig. 3. In the control-group subjects, HF-HRV was significantly higher in Tx compared to T0 ($P = 0.034$) and Tw ($P = 0.038$). In the experimental-group subjects, HF-HRV was significantly lower in T0 compared to Tw ($P < 0.0001$), Tx ($P < 0.0001$), and pTx ($P = 0.047$). Noteworthy, there was no significant difference in Tw compared to Tx and Tx-WB ($P > 0.05$).

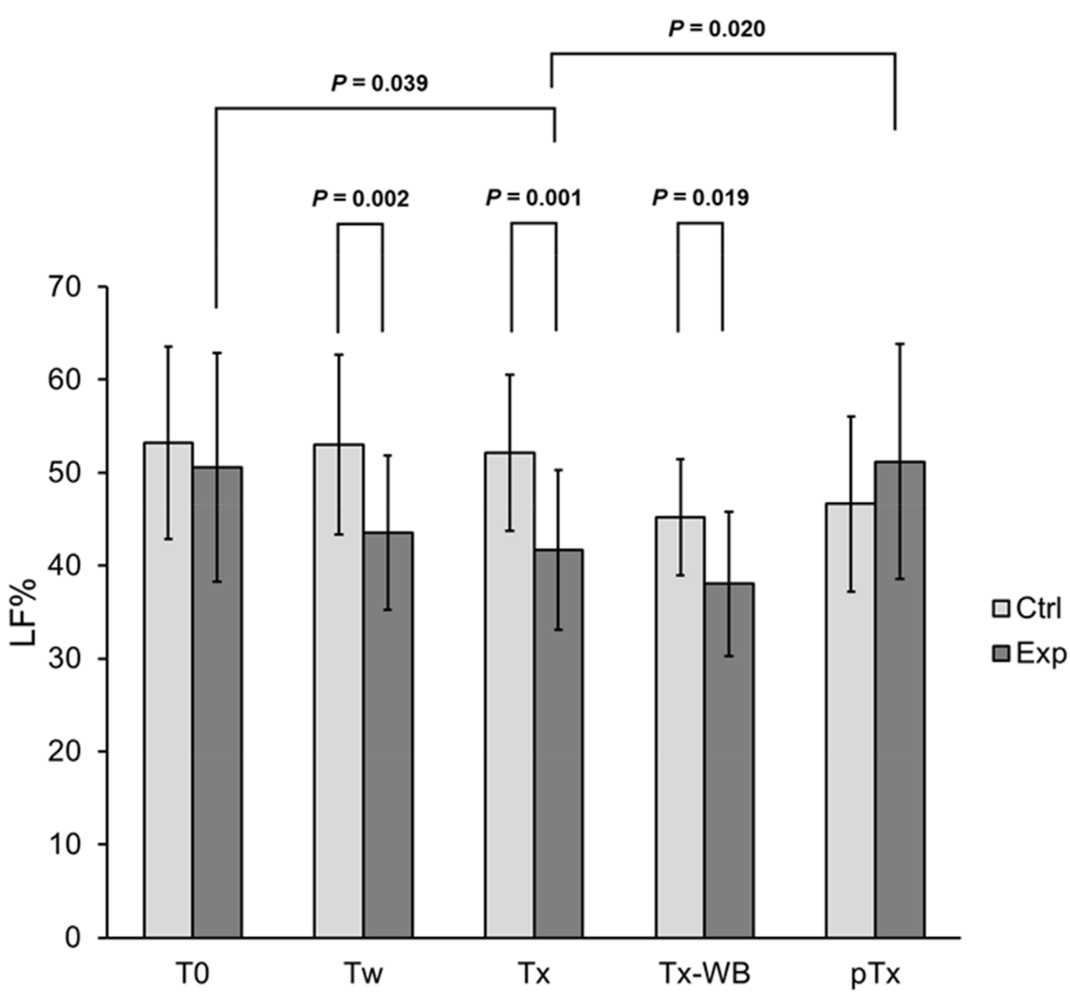

Figure 2 Comparison of percentage of low frequency component of heart rate variability (LF-HRV) between the control (Ctrl) and experimental (Exp) groups across the baseline phase (T0), the waiting phase (Tw), the treatment phase without a weighted blanket (Tx), the treatment phase with a weighted blanket (Tx-WB), and the post-treatment phase (pTx). Error bars represented the standard deviation of the mean.

Intergroup analysis revealed that HF-HRV was higher in the experimental-group subjects during the Tw, Tx-WB, and pTx phases compared to the control-group subjects (Table 1). These results indicate that deep pressure input enhances parasympathetic activity, beginning in the Tw phase and persisting throughout the wisdom tooth extraction period.

For the LF/HF-HRV, significant intra- and intergroup differences were observed (Fig. 4). In the control-group subjects, the LF/HF-HRV was higher in T0 compared to Tx ($P = 0.013$). In contrast, the experimental-group subjects showed the higher LF/HF-HRV in T0 compared to Tw ($P < 0.0001$) and Tx ($P = 0.001$). Intergroup analysis revealed that the LF/HF-HRV was significantly lower in the experimental-group subjects during the Tw compared to the control-group subjects (Table 1). These findings suggest that deep pressure input reduces the sympathetic activity (LF-HRV) while enhancing the parasympathetic activity (HF-HRV) from Tw phase onward, sustaining its effects during the wisdom tooth extraction procedure.

Discussion

The present study investigated whether application of deep pressure input during the waiting phase could modulate ANS responses during the wisdom tooth extraction procedure in healthy adults. The sympathetic and parasympathetic activities of ANS were assessed through the spectral components of HRV. The significant increase in HF-HRV observed in the experimental-group subjects suggests that the effect of deep pressure input, initiated in the waiting phase, persisted throughout the tooth extraction procedures. To the best of our knowledge, this is the first study

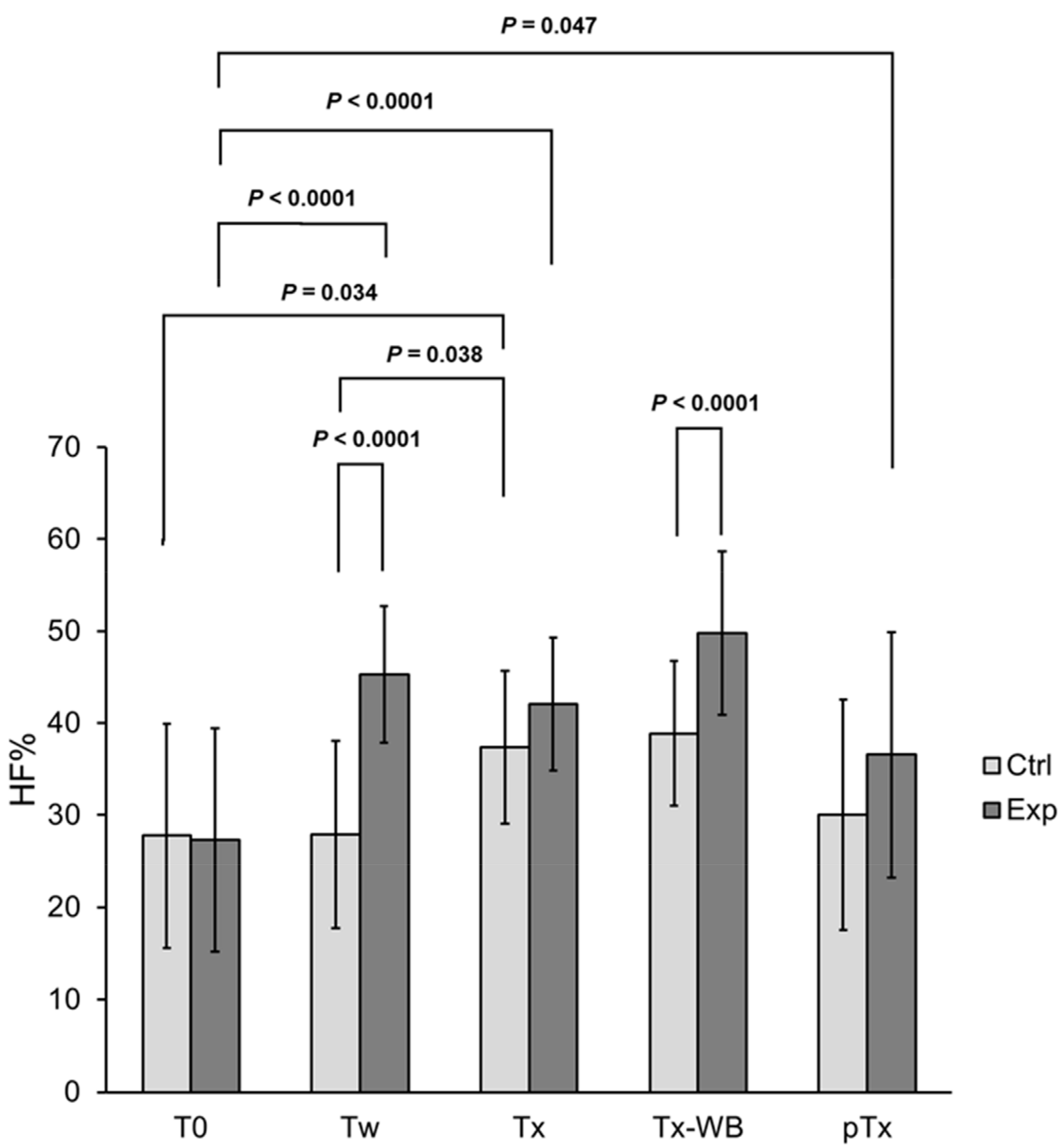

Figure 3 Comparison of percentage of high frequency component of heart rate variability (HF-HRV) between the control (Ctrl) and experimental (Exp) groups across the baseline phase (T0), the waiting phase (Tw), the treatment phase without a weighted blanket (Tx), the treatment phase with a weighted blanket (Tx-WB), and the post-treatment phase (pTx). Error bars represented the standard deviation of the mean.

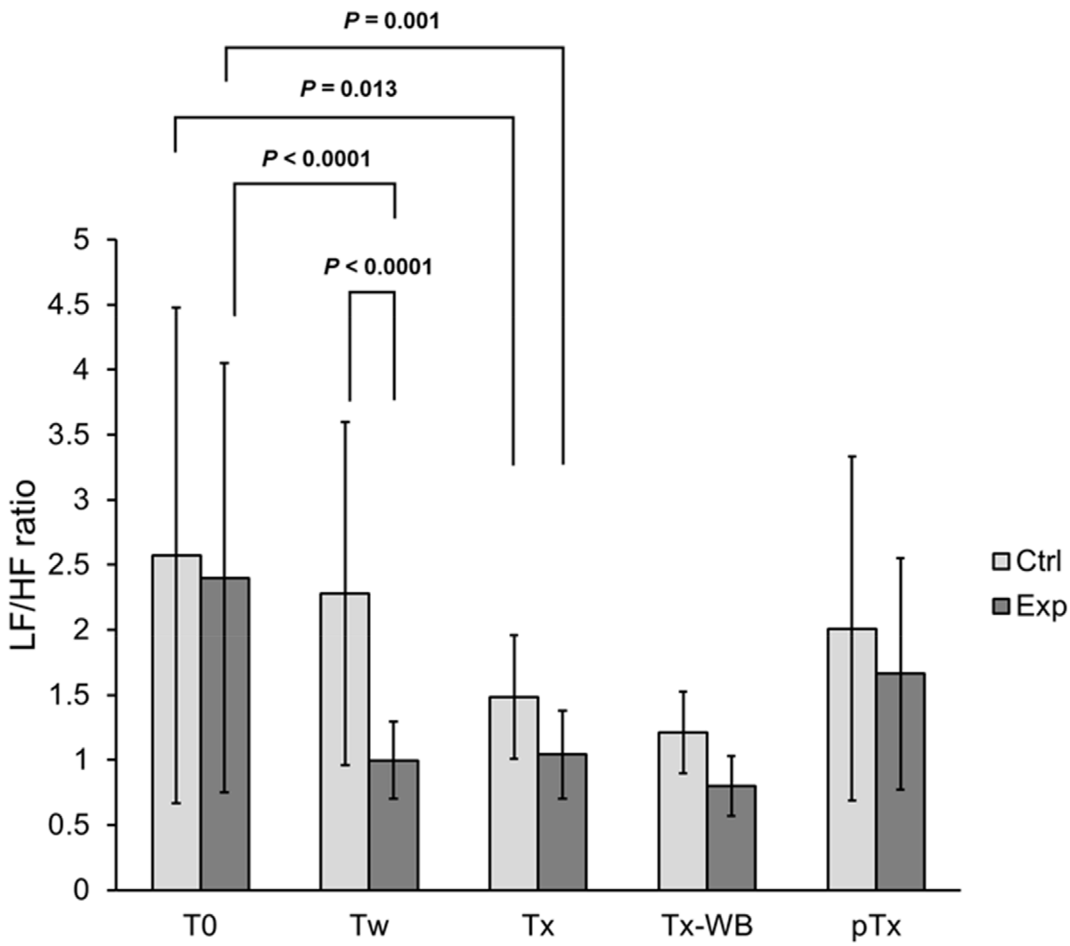

Figure 4 Comparison of ratio of low frequency/high frequency components of heart rate variability (LF/HF-HRV) between the control (Ctrl) and experimental (Exp) groups across the baseline phase (T0), the waiting phase (Tw), the treatment phase without a weighted blanket (Tx), the treatment phase with a weighted blanket (Tx-WB), and the post-treatment phase (pTx). Error bars represented the standard deviation of the mean.

investigating the effect of deep pressure stimulation considering from the waiting period to the wisdom tooth extraction period.

The ANS, composed of the excitatory SNS and the inhibitory PsNS, modulate physiological arousal to adapt to challenges. The elevated HR and increased LF-HRV, coupled with decrease in HF-HRV, are characteristic of heightened arousal states. Conversely, during periods of stability and safety, PsNS activity predominates, resulting in increased HF-HRV and reduced HR.[20,24,25] In this study, the control-group participants exhibited elevated HR and LF-HRV with reduced HF-HRV during the waiting phase (Tw), consistent with stress-related physiological responses. In contrast, the experimental-group participants who experienced deep pressure input via a weighted vest demonstrated significantly lower HR and higher HF-HRV, indicative of the enhanced parasympathetic activity and the reduced stress.[26] These results suggest that the waiting phase itself can induce psychological stress, even if the absence of surgical intervention, and that deep pressure input effectively alleviates this stress by shifting the ANS balance toward the parasympathetic dominance.

During the tooth extraction phases (Tx and Tx-WB), the control-group subjects exhibited an increased LF-HRV, indicating heightened SNS activity and stress. In the experimental-group subjects, however, the HF-HRV remained significantly elevated, and no significant LF-HRV increase was observed, highlighting the sustained parasympathetic effect of deep pressure input. This effect was consistent regardless of deep pressure application sequence, as crossover design mitigated order effects. The weighted deep pressure blanket, applied during the tooth extraction phase, further reinforced parasympathetic activity, reducing stress and promoting the autonomic balance. These findings align with the previous research showing that deep pressure input can shift the ANS from the sympathetic-dominant state to the parasympathetic dominance during stressful conditions such as the wisdom tooth extraction procedures.[17]

The significant HF-HRV increase observed in the experimental-group subjects reflects the inhibitory function of the PsNS, which is associated with stress alleviation and enhanced neurovisceral integration.[18,27,28] The deep pressure input appears to sustain prefrontal cortical modulation of the parasympathetic activity, decreasing the sympathetic activation and supporting ANS homeostasis. This modulation contributes to improved arousal regulation, fostering calmness and effective stress management.

The HRV served as a biomarker in this study, characterizing the ANS influences on the stress regulation and behavioral adaptation. Beyond being an indicator of cardiac health, the HRV reflects the brain's capacity to regulate autonomic responses through integrative the neural pathway.[29—32] Prominent theories, including the polyvagal perspective[33—35] and neurovisceral integration perspective,[32,36,37] highlight the role of prefrontal, limbic, and brainstem structures in the autonomic regulation.[29,32,36,38] The HF-HRV, strongly correlated with prefrontal activation, reflects successful inhibition of sympathetic response and activation of parasympathetic tone.[39] The observed increase in HF-HRV with deep pressure input suggests effective prefrontal modulation of the autonomic activity.

In conclusion, this study demonstrates that deep pressure input via weighted vests or blankets effectively modulates autonomic responses during the wisdom tooth extraction procedure, reducing LF-HRV, increasing HF-HRV, and lowering the LF/HF ratio. These findings highlight the potential of deep pressure input as a therapeutic intervention for stress management in the dental procedures, particularly for individuals with high anxiety or special needs. Further large-scale research is needed to elucidate the underlying mechanisms and optimize the clinical applications of this approach.

Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

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