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Acute Effects of Rope Therapy (Vestibular Stimulation) on Heart Rate Variability Coherence in Taiwanese Social Workers: A Within-Subjects Pilot Study

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Abstract: Background: Social workers represent a high-risk occupational group for chronic stress, burnout, and reduced autonomic regulation. Bottom-up, body-based interventions targeting vestibular-autonomic pathways may offer accessible alternatives to cognitive approaches; however, empirical evidence in helping professions remains limited. **Objective:** To examine acute changes in heart rate variability (HRV) coherence following a single session of Rope Therapy (RT) — a structured vestibular stimulation intervention — in Taiwanese social workers reporting occupational stress and anxiety. **Methods:** Thirteen Taiwanese social workers (12 female, 1 male; ages 25–42 years, M = 31.6, SD = 6.5) completed a single intervention session comprising a pre-intervention HRV measurement, a structured RT protocol involving graded rotational vestibular stimulation, and a post-intervention HRV measurement. HRV was recorded using the emWave Pro system (HeartMath Institute), with coherence score — an index of cardiorespiratory synchronization reflecting autonomic regulation — low/medium/high coherence ratios, and average heart rate as primary outcomes. Within-subjects analyses employed Wilcoxon signed-rank tests, with effect sizes reported as r. **Results:** Mean HRV coherence increased from pre-intervention (M = 1.25, SD = 0.70) to post-intervention (M = 1.75, SD = 0.87), representing a 40% relative increase (Wilcoxon Z = 2.48, p = .013, r = 0.69). High-coherence state proportion increased from M = 47.5% to M = 71.7% (Z = 2.62, p = .009, r = 0.73). Eleven of 13 participants (84.6%) demonstrated improvement in mean coherence. Three distinct response patterns were identified: regulatory improvement (n = 10), transitional regulation (n = 1), and autonomic co-activation (n = 2). The two co-activation cases — one female with mild concurrent sympathetic-parasympathetic engagement, and the only male participant (the oldest in the cohort) showing pronounced sympathetic shift — illustrate response heterogeneity that may reflect novelty effects, demographic moderation, or, hypothetically, trauma-related activation, though these interpretations remain speculative without concurrent clinical data. One participant reported transient mild dizziness, which resolved spontaneously. **Conclusions:** A single session of Rope Therapy was associated with statistically significant improvements in HRV coherence among Taiwanese social workers. The diversity of response patterns — particularly the autonomic co-activation observed in two participants — suggests that vestibular intervention engages multiple autonomic regulatory processes and warrants trauma-informed clinical consideration. These pilot findings support feasibility and warrant controlled investigation with larger samples, concurrent psychological measures, and trauma-history screening.

Keywords: heart rate variability; coherence; vestibular stimulation; rope therapy; social workers; occupational stress; autonomic regulation; trauma-informed practice; pilot study

1. Introduction

1.1 Occupational Stress in Social Workers

Social workers constitute a recognized high-risk occupational group for chronic stress, burnout, and secondary traumatic stress (Bride, 2007; Lloyd et al., 2002). Prevalence estimates for clinically significant burnout among social work professionals range from 30% to 60% across international samples (Kim & Stoner, 2008). Contributing factors include high caseloads, exposure to client trauma, emotional labor demands, organizational constraints, and limited recovery resources (Tang, 2009; Wagaman et al., 2015).

In East Asian contexts, occupational stress in helping professions is further compounded by cultural norms favoring emotional restraint, hierarchical workplace structures, and limited normalization of help-seeking behavior (Tsai, 2017). These cultural factors may render conventional cognitive-behavioral or talk-based interventions less accessible or culturally congruent, highlighting the need for alternative intervention modalities (Low & McCraty, 2018).

1.2 Heart Rate Variability as an Index of Autonomic Regulation

Heart rate variability (HRV) — the beat-to-beat variation in cardiac intervals — has emerged as a sensitive, non-invasive marker of autonomic nervous system function and adaptive capacity under stress (Shaffer & Ginsberg, 2017; Thayer et al., 2012). Reduced HRV is consistently associated with anxiety, depression, and chronic stress, reflecting diminished parasympathetic activity and reduced regulatory flexibility (Chalmers et al., 2014).

The neurovisceral integration model conceptualizes HRV as an index of dynamic regulatory capacity rather than a static trait (Thayer et al., 2012; Appelhans & Luecken, 2006). Within this framework, HRV coherence — defined as the rhythmic synchronization between cardiac, respiratory, and vascular oscillations — represents an integrated marker of cardiorespiratory entrainment and autonomic balance (McCraty & Zayas, 2014).

Our prior research in Hong Kong working populations established significant correlations between HRV indices and self-reported workplace stress, with notable findings regarding emotional stress, intention to quit, and relational tension (Low & McCraty, 2018). Subsequent case-based work demonstrated that HRV biofeedback interventions can produce measurable shifts in physiological coherence among stressed workers (Low & Wong, 2018).

1.3 Rope Therapy: A Structured Vestibular-Proprioceptive Intervention

Rope Therapy (RT), developed in Hong Kong through integration of rope-access engineering and sensory integration principles, provides controlled vestibular stimulation through graded rotational movement, suspended balance challenges, and proprioceptive loading (Lam et al., 2024). The intervention is grounded in a bottom-up regulatory framework, hypothesizing that vestibular input engages subcortical circuits implicated in autonomic regulation, including brainstem nuclei, cerebellar networks, and limbic structures (Porges, 2007; Balaban & Thayer, 2001).

A growing program of research has documented RT effectiveness in pediatric populations with neurodevelopmental conditions. Lam et al. (2024) reported significant improvements in concentration, emotional regulation, and family harmony among 69 children with special educational needs following 12 weeks of home-based RT. A subsequent pilot study by Lam, Low, Wong, and Chau (2025) demonstrated measurable temperament shifts in 35 neurodiverse adolescents using the Taylor-Johnson Temperament Analysis. Most recently, Lam et al. (2026) provided practice-based evidence for RT clinical effectiveness in 76 youth with neurodevelopmental conditions, demonstrating superior outcomes compared to standard occupational therapy.

While these pediatric findings are encouraging, the application of RT to adult populations — particularly those experiencing occupational stress — has not been empirically examined. Furthermore, the proposed autonomic mechanisms underlying RT effects have not been directly tested using physiological markers.

1.4 Theoretical Framework

The proposed mechanisms by which vestibular stimulation may modulate autonomic function include:

1. **Vestibular-autonomic pathways:** Direct projections from vestibular nuclei to brainstem autonomic control centres — the rostral ventrolateral medulla (which regulates sympathetic "fight-or-flight" outflow) and the nucleus tractus solitarius (which integrates parasympathetic and cardiovascular signals) — modulate sympathetic and parasympathetic activity (Balaban & Thayer, 2001; Yates & Bronstein, 2005).
2. **Polyvagal engagement:** Rhythmic, graded movement may facilitate ventral vagal activation supporting social engagement and parasympathetic dominance (Porges, 2007, 2011).
3. **Interoceptive recalibration:** Vestibular input enhances interoceptive awareness, supporting emotion regulation through improved internal signal detection (Craig, 2002; Critchley et al., 2004).
4. **Cardiorespiratory entrainment:** Rhythmic movement may promote synchronization between cardiac and respiratory rhythms, similar to resonance effects observed in HRV biofeedback (Lehrer et al., 2000).

In plain terms, HRV coherence reflects the degree of cardiorespiratory synchronization — the extent to which heart rhythm, breathing, and blood-pressure oscillations move together in a smooth, ordered pattern. Higher coherence scores indicate a more regulated and flexible autonomic state that is associated with improved stress resilience and emotional self-regulation.

1.5 Study Aims and Hypotheses

The present pilot study examined acute HRV coherence responses to a single session of Rope Therapy in Taiwanese social workers experiencing self-reported occupational stress and anxiety. We hypothesized that:

H1: Mean HRV coherence would increase significantly from pre- to post-intervention.

H2: The proportion of session time in high-coherence states would increase significantly.

H3: Response patterns would demonstrate within-sample heterogeneity, reflecting individual differences in autonomic engagement.

Given the exploratory pilot nature of this investigation, we emphasized effect size estimation and pattern identification over confirmatory hypothesis testing. Particular attention was paid to heterogeneity of response, including profiles potentially indicative of complex autonomic engagement that may have implications for trauma-informed clinical implementation.

2. Methods

2.1 Design

This study employed a within-subjects, pre-post pilot design. Each participant served as their own control, with HRV measured immediately before and immediately after a single structured Rope Therapy intervention session.

2.2 Participants

2.2.1 Sample

Thirteen Taiwanese social workers participated in this study. All participants self-identified as experiencing occupational stress and anxiety related to their professional roles. Demographic characteristics are presented in **Table 1**.

Table 1. Participant Demographics

Characteristic	Value
N	13
Sex	12 female (92.3%), 1 male (7.7%)
Age range (years)	25–42
Mean age (SD)	31.6 (6.5)
Median age	30
Profession	Social worker (100%)
Nationality	Taiwanese (100%)
Age distribution	25–29: n = 6 (46.2%); 30–34: n = 3 (23.1%); 35–42: n = 4 (30.8%)

2.2.2 Inclusion and Exclusion Criteria

Inclusion criteria: (a) employment as a social worker; (b) self-reported stress and anxiety related to occupational role; (c) age ⩾ 18 years; (d) ability to provide informed consent.

Exclusion criteria: (a) medical contraindications to vestibular stimulation (e.g., active vestibular disorders, severe cardiovascular disease); (b) caffeine or food consumption within two hours prior to the session; (c) known pregnancy; (d) recent vestibular pathology.

2.2.3 Recruitment and Consent

Participants were recruited through a single structured group session coordinated by the Rope Therapy Association on December 29, 2025. Data were collected as part of routine clinical service with informed consent for anonymized research use, in accordance with the ethical principles outlined in the Declaration of Helsinki. All participants received standard pre-session instructions including caffeine and food restrictions.

2.3 Intervention: Rope Therapy Protocol

The Rope Therapy intervention followed the standardized Version 3.0 protocol previously described in Lam et al. (2026). The full protocol manual specifies session structure, timing, and safety procedures.

2.3.1 Session Structure

Each participant completed an individual session comprising the following sequence (total approximate duration: 45 minutes):

1. **Introduction and baseline assessment** (10 min): Brief explanation of the procedure, baseline questionnaire including emotional distress, sleep quality, and pain ratings (1–10 scale), and review of safety protocols.
2. **HRV pre-test** (5 min): Seated upright, eyes closed, ear-clip pulse sensor on left earlobe, no intentional breathing manipulation. Participants were instructed to keep the head stable and avoid intentional mindfulness or breath regulation.
3. **Mounting and positioning** (5 min): Participants were positioned on the RX rotational platform with head aligned to the central axis, supported by an eye mask and cushion. They were informed they could stop at any time if discomfort occurred.
4. **Round 0 (Familiarization)** (~5 min): Speed levels 9 → 11, with 30–60 second adaptation at each level. Participants confirmed perception of rotation, acceleration, directional awareness, and reversal sensation following sudden stops.
5. **Rounds 1–3 (Intervention)** (~15 min): Three structured rotational cycles at speeds 11–15, each including:
   • Acceleration phase with 30–60 second adaptation
   • Sudden stop with reversal sensation perception
   • Refocus on rotational sensation until reversal sensation ceased
   • Resumption to original speed The third round concluded with graded deceleration (15 → 11), 60–90 seconds of slow rotation at level 11, and final sudden stop.
6. **Dismount and transition** (~2 min): Verification of physical comfort and transition to the post-test waiting room.
7. **HRV post-test** (5 min): Same protocol as pre-test, conducted in a separate waiting room.
8. **Group debrief** (~3 min): Non-individual group discussion of subjective experiences, conducted in a group setting.

2.3.2 Data Collection Logistics

Participants rotated sequentially through the intervention room for HRV pre-test, RT intervention, and then to the waiting room for HRV post-test, allowing efficient throughput while maintaining individual measurement integrity.

2.4 Measures

2.4.1 Heart Rate Variability

HRV coherence reflects the degree of cardiorespiratory synchronization, with higher scores indicating a more regulated and flexible autonomic state associated with improved stress resilience. HRV was measured using the emWave Pro system (HeartMath Institute, Boulder Creek, CA, USA), employing photoplethysmographic detection via a left-earlobe pulse sensor. This system has been validated for capturing real-time HRV data and has been employed in our prior published research (Low & McCraty, 2018; Low & Wong, 2018).

The following primary outcomes were extracted from each recording session:

- **Average coherence score:** A continuous index reflecting power concentration in the 0.04–0.26 Hz coherence band relative to total spectral power, ranging from 0 to higher values, with higher scores indicating greater cardiorespiratory synchronization.
- **Low coherence proportion (%):** Percentage of recording time spent in low-coherence states, indexing sympathetic-dominant activity.
- **Medium coherence proportion (%):** Percentage of time in transitional states.
- **High coherence proportion (%):** Percentage of time in high-coherence states, indexing parasympathetic-dominant cardiorespiratory entrainment.
- **Average heart rate (bpm):** Mean heart rate across the recording. The system was operated at Challenge Level 1 (lowest difficulty threshold), consistent with the standardized RT protocol.
- **Recording duration:** Recording durations were determined by the practical constraints of the group session logistics and standardized throughput across participants. While shorter than the traditional 5-minute recommendation for standard time- and frequency-domain HRV analysis (Shaffer & Ginsberg, 2017), short-segment recordings are considered adequate for capturing the emWave coherence metric, which reflects real-time rhythmic entrainment rather than long-term variability norms. The durations were applied consistently across pre- and post-conditions and fall within the range used in our prior published HRV coherence research (Low & McCraty, 2018; Low & Wong, 2018). We nonetheless acknowledge duration variability as a measurement limitation (see Section 4.7).

2.4.2 Adverse Events

Adverse events were monitored throughout sessions through observer documentation and post-session inquiry. Mild events (e.g., transient dizziness, nausea) were documented but did not require session termination unless severity warranted.

2.5 Data Analysis

2.5.1 Descriptive Statistics

Means, standard deviations, medians, and ranges were calculated for all primary outcomes at pre- and post-intervention timepoints.

2.5.2 Inferential Statistics

Given the small sample size and non-normal distribution of paired difference scores, we employed the **Wilcoxon signed-rank test** (non-parametric, paired) for within-subjects pre-post comparisons. Effect sizes were reported as **r** (computed as $Z/\sqrt{N}$), with conventional interpretations of small (0.10), medium (0.30), and large (0.50) effects (Cohen, 1988; Rosenthal, 1991).

Two-tailed significance was set at $\alpha = .05$.

2.5.3 Response Pattern Classification

To explore heterogeneity in autonomic response, we developed a three-pattern classification framework based on pre-post changes in coherence score and high/low coherence proportions:

- **Pattern A — Regulatory Improvement:** Increase in coherence score and high-coherence proportion, with decrease in low-coherence proportion.
- **Pattern B — Transitional Regulation:** Decrease in low-coherence proportion with stable or modestly increased high-coherence proportion, but reduction in overall coherence score, suggesting ongoing reorganization.
- **Pattern C — Autonomic Co-activation:** Simultaneous increase in both low- and high-coherence proportions, suggesting concurrent sympathetic and parasympathetic engagement.

2.5.4 Software

All analyses were conducted using standard statistical procedures, with effect size calculations performed manually following established formulas.

3. Results

3.1 Sample Description and Session Characteristics

All 13 participants completed both pre- and post-intervention HRV measurements (100% completion rate). Pre-intervention recording duration ranged from

2:05 to 4:14 minutes (M = 2:24, SD = 0:31). Post-intervention recording duration ranged from 2:06 to 4:14 minutes (M = 2:48, SD = 0:38).

3.2 Primary Outcome: HRV Coherence Score

Wilcoxon signed-rank analysis revealed a statistically significant increase in mean HRV coherence from pre- (M = 1.25, SD = 0.70) to post-intervention (M = 1.75, SD = 0.87), Z = 2.48, $p = .013$, r = 0.69 (large effect). This represents a 40% relative increase in mean coherence following a single RT session.

Eleven of 13 participants (84.6%) demonstrated an increase in coherence score; two participants (15.4%) showed a decrease (Table 2).

3.3 Secondary Outcome: High-Coherence Proportion

The proportion of session time spent in high-coherence states increased significantly from pre- (M = 47.5%, SD = 36.2%) to post-intervention (M = 71.7%, SD = 22.8%), Z = 2.62, $p = .009$, r = 0.73 (large effect). Eleven of 13 participants (84.6%) demonstrated increases in high-coherence proportion.

3.4 Tertiary Outcomes: Low-Coherence Proportion and Heart Rate

Low-coherence proportion decreased from pre- (M = 22.2%, SD = 22.4%) to post-intervention (M = 13.6%, SD = 16.1%), with directional change in 9 of 13 participants. Average heart rate showed a modest decrease from pre- (M = 86.8 bpm, SD = 12.0) to post-intervention (M = 81.8 bpm, SD = 9.7).

3.5 Paired Pre-Post Data

Complete paired data are presented in **Table 2**.

Table 2. Pre-Post Heart Rate Variability Outcomes by Participant

ID	Age	Sex	Pre Coh	Post Coh	Δ Coh	Pre High%	Post High%	Δ High%	Pattern
P01	30	F	0.4	0.6	+0.2	0	16	+16	A
P02	41	F	2.3	2.7	+0.4	97	94	−3	A
P03	25	F	1.7	1.4	−0.3	70	65	−5	B
P04	38	F	1.7	2.7	+1.0	79	100	+21	A
P05	25	F	2.1	2.3	+0.2	74	97	+23	A
P06	26	F	0.6	2.2	+1.6	4	76	+72	A
P07	25	F	0.6	1.3	+0.7	13	86	+73	A
P08	33	F	1.5	3.3	+1.8	60	100	+40	A
P09	27	F	1.0	1.7	+0.7	32	87	+55	A
P10	29	F	0.6	0.7	+0.1	27	37	+10	A
P11	30	F	1.2	1.3	+0.1	63	70	+7	C
P12	40	F	0.4	1.2	+0.8	8	44	+36	A
P13	42	M	2.2	1.3	−0.9	91	58	−33	C
Mean (SD)	31.6 (6.5)	–	1.25 (0.70)	1.75 (0.87)	+0.50	47.5 (36.2)	71.7 (22.8)	+24.2	–

Note. Coh = average coherence score; High% = percentage of session time in high-coherence state. ***Δ values represent percentage-point changes (post – pre), not relative percentage changes.*** *Patterns: A = Regulatory Improvement; B = Transitional Regulation; C = Autonomic Co-activation. Participants are presented in anonymized order; original identifiers are retained in study records.*

3.6 Response Pattern Distribution

Application of the three-pattern classification framework yielded the following distribution:

- **Pattern A (Regulatory Improvement):** n = 10 (76.9%)
- **Pattern B (Transitional Regulation):** n = 1 (7.7%)
- **Pattern C (Autonomic Co-activation):** n = 2 (15.4%)

All 13 participants (100%) demonstrated an autonomic response to the intervention, though responses varied in pattern.

3.7 Adverse Events

One participant (P07; female, age 25) reported transient mild dizziness during the rotational sequences. The symptom resolved spontaneously within the session and did not require intervention or session termination. No serious adverse events occurred. No participant withdrew from the session.

3.8 Notable Individual Responses

Three participants demonstrated particularly large coherence improvements ($\Delta \geqslant 1.0$): P04 (+1.0), P06

(+1.6), and P08 (+1.8). All three had moderate-to-low pre-intervention coherence (range: 0.6–1.7), suggesting greater capacity for change in less initially regulated states.

The two Pattern C cases warrant individual consideration:

• **P11** (female, age 30) showed mild co-activation with modest increases in both low- and high-coherence proportions.

• **P13** (male, age 42) — the only male participant and oldest member of the cohort — demonstrated a notable decline in coherence score (−0.9) with simultaneous increase in low-coherence (+18%) and decrease in high-coherence (−33%) proportions.

4. Discussion

4.1 Principal Findings

This pilot study examined acute HRV coherence responses to a single session of Rope Therapy in Taiwanese social workers reporting occupational stress and anxiety. Three principal findings emerged:

First, mean HRV coherence increased by 40% from pre- to post-intervention, a statistically significant change with large effect size (r = 0.69). High-coherence proportion increased by 24 percentage points (r = 0.73). Eleven of 13 participants (84.6%) showed improvement, suggesting a robust acute physiological effect.

Second, the magnitude of change exceeds typical effect sizes reported for brief stress-reduction interventions in working populations (Goyal et al., 2014), though direct comparison is limited by the absence of a control condition. The within-subjects effect sizes are consistent with those reported in our prior HRV biofeedback case work (Low & Wong, 2018) and with broader literature on acute autonomic interventions (Lehrer & Gevirtz, 2014).

Third, the identification of three response patterns — regulatory improvement, transitional regulation, and autonomic co-activation — highlights the heterogeneity of autonomic responses to vestibular stimulation. This pattern-based framework offers a more nuanced characterization than binary "responder/non-responder" classification and may guide individualized intervention planning in future research.

4.2 Interpretation Within the Existing Evidence Base

The findings extend our research group's prior work on Rope Therapy (Lam et al., 2024, 2025, 2026) into an adult occupational stress population, providing the first physiological evidence that RT engages autonomic regulatory systems acutely. This complements the behavioral, temperamental, and clinical outcomes documented in pediatric populations.

The findings also extend our prior HRV research in Hong Kong working populations (Low & McCraty, 2018; Low & Wong, 2018) by demonstrating that targeted vestibular intervention can produce measurable shifts in coherence among stressed professionals — a population for whom we previously documented significant negative correlations between perceived stress and HRV indices.

4.3 Theoretical Implications

The observed coherence improvements support the hypothesized vestibular-autonomic mechanism of RT. Several pathways may contribute:

Vestibular-autonomic coupling. Direct neural projections from the vestibular nuclei to brainstem autonomic control centres — including the rostral ventrolateral medulla, a key regulator of sympathetic outflow — provide an anatomical basis for rotational stimulation to influence sympathetic-parasympathetic balance (Balaban & Thayer, 2001; Yates & Bronstein, 2005).

Polyvagal engagement. The combination of rhythmic movement, controlled exposure to perturbation (sudden stops), and recovery cycles may facilitate ventral vagal activation consistent with polyvagal theory (Porges, 2007, 2011). The post-intervention shift toward high-coherence dominance is consistent with parasympathetic engagement.

Interoceptive recalibration. The RT protocol explicitly directs attention to bodily sensations (rotation, reversal, stability), potentially enhancing interoceptive awareness. Improved interoception is associated with better emotion regulation and may underlie the observed coherence shifts (Craig, 2002; Critchley et al., 2004).

4.4 The Three-Pattern Response Framework

The three-pattern framework offers important nuance to standard interpretation of HRV change:

Pattern A (Regulatory Improvement). Characterized by the classic profile of decreased sympathetic and increased parasympathetic activity. Observed in the majority of participants, this pattern reflects the expected outcome of effective autonomic regulation.

Pattern B (Transitional Regulation). Observed in one participant (P03), this pattern showed reduction in both low- and high-coherence proportions with overall coherence score decrease. This may reflect ongoing physiological reorganization in which sympathetic activation is reduced but full cardiorespiratory synchronization has not yet been achieved (Laborde et al., 2017). Coherence score, while a useful index, is influenced by breathing patterns and waveform smoothness; a reduction in coherence score does not necessarily indicate worsening regulation when low-coherence activity has decreased (Thayer et al., 2012).

Pattern C — Autonomic Co-activation

Two participants exhibited simultaneous increases in both sympathetic-associated (low-coherence) and parasympathetic-associated (high-coherence) activity, a pattern we have termed *autonomic co-activation*. This profile diverges meaningfully from both Pattern A and Pattern B, and warrants careful interpretation given its theoretical significance and clinical implications.

Defining the Pattern

In contrast to simple sympathetic dominance — characterized by elevated low-coherence with suppressed high-coherence activity — Pattern C reflects a *mixed arousal state* in which heightened physiological activation co-occurs with active regulatory engagement (Berntson et al., 1991; Berntson & Cacioppo, 2007). Such co-activation has been described in the broader autonomic literature as evidence of dynamic regulatory effort under conditions of increased arousal (Thayer et al., 2012; Friedman, 2007), and is theoretically distinguishable from autonomic dysregulation per se.

Importantly, the presence of preserved or enhanced high-coherence activity alongside elevated low-coherence activity may indicate that regulatory capacity remains intact even under conditions of physiological arousal — a profile potentially more adaptive than parasympathetic withdrawal or sympathetic-only activation (Porges, 2007; Thayer & Lane, 2009).

Possible Mechanisms

Several non-mutually-exclusive interpretations may account for the Pattern C profile observed in our two participants. We present these as hypotheses for future investigation rather than confirmed mechanisms, given that direct subjective and clinical data were not collected in this pilot.

1. Increased Sensory and Emotional Engagement. Vestibular stimulation produces robust sensory input that may activate interoceptive and emotional processing networks (Craig, 2002; Lopez & Blanke, 2011). Some participants may experience heightened internal awareness during and after rotation, manifesting as increased autonomic arousal alongside concurrent regulatory effort. This interpretation positions Pattern C as a marker of *adaptive engagement* rather than dysregulation.

2. Novelty and Salience Response. As Rope Therapy is an unfamiliar intervention, particularly for participants without prior vestibular training experience, novelty-induced arousal may contribute to elevated sympathetic activity. Concurrent parasympathetic engagement may reflect successful regulation of this novelty response (Bradley & Lang, 2007).

3. Trauma-Related Activation: A Hypothesized but Unverified Mechanism. A third possibility, consistent with somatic trauma frameworks, is that vestibular stimulation may activate previously unprocessed physiological responses associated with stress or trauma history. Body-based interventions have been theorized to engage subcortical structures involved in implicit threat memory, potentially eliciting transient autonomic activation as part of a regulatory "completion" process (van der Kolk, 2014; Levine, 1997; Ogden et al., 2006). Within polyvagal theory, this profile could reflect oscillation between defensive mobilization and ventral vagal regulation as the autonomic system processes salient sensory input (Porges, 2011; Dana, 2018).

We emphasize that this interpretation is *speculative in the context of the present data*. Trauma-related activation cannot be inferred from HRV patterns alone in the absence of validated trauma assessment, subjective distress reports, or longitudinal clinical data (Schnurr & Green, 2004). Furthermore, Pattern C is not pathognomonic of any specific psychological state — the same physiological profile could arise from multiple distinct origins (Berntson & Cacioppo, 2007).

4. Demographic Moderation. P13 — the only male participant and the oldest member of the cohort (age 42) — demonstrated the most pronounced Pattern C response. Both sex and age have established associations with HRV characteristics (Koenig & Thayer, 2016; Umetani et al., 1998), with older adults and males generally exhibiting different baseline HRV profiles than younger females. The single-case nature of P13's profile precludes inferential analysis, but the demographic context suggests that sex- and age-related autonomic characteristics may moderate response to vestibular intervention. Notably, P13 also demonstrated the highest baseline coherence score in the male/older subgroup, raising the possibility of a *ceiling effec*t in which already-regulated participants show different response trajectories than less-regulated participants.

5. Ceiling Effect and Regression Considerations. P13's elevated baseline coherence (2.2, near the upper range of the sample) introduces the possibility that statistical regression to the mean contributed to the observed decline. However, the *magnitude* of P13's coherence decrease (−0.9), combined with the simultaneous shift toward low-coherence dominance, exceeds what would be expected from regression alone, suggesting genuine physiological response.

Implications for Interpretation

The pattern of increased high-coherence proportion *alongside* elevated low-coherence states in P11 and decreased high-coherence with elevated low-coherence in P13 represent meaningfully different profiles within the Pattern C category. P11's mild co-activation is consistent with adaptive engagement under increased arousal, while P13's profile — with notable decline in coherence score and high-coherence dominance — suggests a more pronounced shift toward sympathetic engagement.

Crucially, neither pattern necessarily indicates harm or deterioration. Within autonomic flexibility models, transient sympathetic activation in response to novel stimuli is a normal regulatory feature, particularly when followed by parasympathetic recovery (Thayer et al., 2012). The absence of post-session follow-up data prevents examination of whether P13's response reflected an acute activation phase that subsequently resolved into improved regulation — a possibility that warrants longitudinal investigation in future research.

Recommendations for Future Investigation

The Pattern C cases highlight the importance of:

1. **Concurrent subjective measures** to distinguish among the proposed interpretations (e.g., novelty response vs. emotional activation vs. regulatory effort).

2. **Trauma history screening** in populations where trauma-related activation is plausible (e.g., social workers exposed to client trauma; first responders; trauma survivors).

3. **Extended post-session monitoring** to track autonomic recovery trajectories beyond the immediate post-intervention measurement.

4. **Sex- and age-stratified sampling** to examine demographic moderators systematically.

5. **Clinical safety protocols** for body-based interventions that include observation for delayed activation responses, particularly in trauma-exposed populations.

A Note on Clinical Caution

We recommend that clinicians delivering Rope Therapy or similar vestibular interventions be trained to recognize and respond to autonomic co-activation patterns, regardless of their underlying mechanism. While Pattern C does not necessarily indicate harm, the possibility of trauma-related activation in vulnerable populations warrants careful screening, monitoring, and integration of trauma-informed practice principles (SAMHSA, 2014). This is particularly relevant in helping professions such as social work, where occupational exposure to client trauma is documented (Bride, 2007; Wagaman et al., 2015) and where secondary traumatic stress may render practitioners more susceptible to embodied activation responses.

4.5 Clinical Implications

If replicated in controlled trials, these findings have several implications:

For occupational health. A single 30–45 minute session producing measurable physiological shifts could be feasible as a workplace stress intervention for high-burnout helping professions. Social workers, who often have limited time for self-care, may benefit from time-efficient, body-based interventions.

For culturally congruent care. In East Asian contexts where verbal disclosure of distress may be culturally constrained, body-based interventions like RT offer an alternative pathway to autonomic regulation that does not require emotional articulation.

For complementary integration. RT should be considered as a complementary intervention rather than a replacement for evidence-based treatments. Its potential role within multimodal stress management programs warrants investigation.

4.6 Strengths

Strengths of this pilot study include: (a) within-subjects design enabling each participant to serve as their own control; (b) use of a standardized, manualized RT protocol (Lam et al., 2026); (c) employment of validated emWave Pro HRV methodology consistent with our prior research (Low & McCraty, 2018; Low & Wong, 2018); (d) homogeneous, clinically meaningful sample (Taiwanese social workers); (e) 100% completion rate; (f) transparent reporting of adverse events and non-responder cases; and (g) introduction of a pattern-based response classification framework.

4.7 Limitations

Several limitations must be acknowledged.

Absence of psychological outcome measures. The most significant limitation of this study is that no self-report psychological outcome measures (e.g., State-Trait Anxiety Inventory, STAI-S; Perceived Stress Scale, PSS-10) were collected. Although the study's title and rationale foreground occupational stress and anxiety, the design captured only a physiological index of autonomic regulation. Consequently, we cannot establish whether the observed physiological changes correspond to subjective changes in perceived stress, anxiety, or mood state. This substantially limits the psychological interpretability of the coherence findings and represents the primary constraint on the conclusions that can be drawn. Future studies must incorporate validated psychological instruments, administered pre- and post-intervention, to determine whether physiological coherence shifts translate into meaningful subjective improvement.

Absence of control group. The single-arm design precludes causal inference. Observed changes may reflect:

- *Time effects:* natural autonomic variation over the session period
- *Regression to the mean:* participants selected for stress may improve regardless of intervention
- *Expectancy effects:* belief in treatment efficacy
- *Therapeutic relationship:* attention from clinicians independent of RT
- *Practice effects:* familiarity with HRV measurement at post-test

A randomized controlled trial with appropriate comparison conditions (e.g., quiet rest, alternative movement) is necessary to establish specificity of effects.

Small sample size. With n = 13, statistical power for subgroup analyses is limited, and findings may not generalize to broader populations. The sample also showed significant sex imbalance (12 female, 1 male), reflecting the predominantly female social work workforce but limiting examination of sex differences.

Single-session design. Effects of repeated RT sessions, optimal dosing, and durability of acute effects remain unexamined.

Coherence as proprietary metric. While the emWave coherence score has been employed in published research, it is a proprietary index and may not be directly comparable to standard HRV metrics (SDNN, RMSSD, LF/HF). Future work should incorporate standard time- and frequency-domain HRV indices.

Sample homogeneity. Findings in Taiwanese female social workers may not generalize to other professions, cultures, or sex distributions.

Recording duration variability. Pre- and post-test recording durations varied across participants (2:05–4:14 minutes), introducing potential measurement variability.

4.8 Future Directions

Building on this pilot, several next steps are warranted:

1. **Randomized controlled trial.** A larger sample ($n \geqslant 60$) with active control (e.g., quiet rest, gentle stretching) and appropriate randomization.
2. **Multimodal physiological assessment.** Integration of standard HRV indices (SDNN, RMSSD, LF, HF, LF/HF), salivary cortisol, and respiration measurement to elucidate mechanisms.
3. **Concurrent psychological measures.** Pre-post administration of validated instruments (STAI-S, PSS-10, POMS) to link physiological and subjective changes.
4. **Dose-response investigation.** Examination of single-session versus multi-session protocols, with follow-up assessment of effect durability.
5. **Sex and age moderators.** Recruitment of more sex-balanced samples to examine demographic moderators of response patterns, particularly the Pattern C profile observed in our male participant.
6. **Population extension.** Examination of RT in other high-stress occupational groups (healthcare workers,

teachers, first responders) and in clinical populations with anxiety and trauma-related disorders.

7. **Mechanism studies.** Neuroimaging investigation of vestibular-limbic-autonomic circuit engagement during and following RT.

5. Conclusion

This pilot study provides preliminary evidence that a single session of Rope Therapy is associated with acute, statistically significant improvements in HRV coherence among Taiwanese social workers experiencing occupational stress and anxiety. Eleven of 13 participants (84.6%) demonstrated measurable improvement, with mean coherence increasing by 40% and high-coherence proportion increasing by 24 percentage points from pre- to post-intervention.

The identification of three distinct response patterns — regulatory improvement, transitional regulation, and autonomic co-activation — extends the conventional binary "responder/non-responder" framework and offers a more nuanced characterization of autonomic response to vestibular stimulation. Of particular theoretical and clinical importance is the autonomic co-activation pattern observed in two participants, which may reflect adaptive engagement under novelty, demographic moderation by sex and age, or — as a hypothesis warranting future investigation — trauma-related physiological activation. While the present pilot cannot confirm any specific mechanism for these co-activation responses, their occurrence underscores the need for trauma-informed implementation of body-based interventions, particularly in occupational populations such as social workers who are routinely exposed to client trauma and may be susceptible to secondary traumatic stress.

Several limitations qualify these findings. Most notably, no psychological outcome measures were collected — a major limitation given the study's focus on stress and anxiety — meaning we cannot confirm whether the observed physiological changes correspond to subjective state changes. Further limitations include the absence of a control group, the small and demographically homogeneous sample, and the single-session design.

These findings extend our research group's prior work on Rope Therapy in pediatric neurodiverse populations (Lam et al., 2024, 2025, 2026) into adult occupational stress contexts, and complement our earlier HRV research in Hong Kong working populations (Low & McCraty, 2018; Low & Wong, 2018). Rope Therapy may represent a promising body-based, time-efficient, and culturally adaptable intervention for autonomic regulation in high-burnout helping professions. Future controlled trials integrating physiological, psychological, and clinical assessments — with particular attention to demographic moderators, trauma history, and post-session recovery trajectories — will be necessary to establish the specificity, durability, and safe implementation of these effects.

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