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Utilising Continuous HRV Biofeedback Data for Autonomic Nervous System Regulation in ME/CFS Relapse Management

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Case Report

Keywords: Myalgic Encephalomyelitis/Chronic Fatigue Syndrome (ME/CFS), Post exertional malaise (PEM), Heart rate variability (HRV), Autonomic nervous system (ANS), Neuroimmune lag, Pacing, Health coaching, RMSSD

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K. Duder: Conceptualisation, methodology, health coaching, data synthesis and lead manuscript drafting. L. Catchpole: Patient-partner; provision of HRV data, observational lived-experience insights, and contribution to the interpretation of results. Both authors reviewed and approved the final manuscript.

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Declaration of interest statement

K. Duder is a certified Firstbeat Life practitioner and founder of Inside Matters Ltd, which utilises Firstbeat Life HRV tracking technology within their private practice for physiological monitoring with clients. She provides consultancy to health practitioners on the clinical application of Firstbeat HRV tracking. The data was collected independently during standard client sessions and Firstbeat received no financial or other incentives and played no role in study design, data analysis, or the decision to publish. The authors declare no other competing interests.

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Abstract

Background: Myalgic Encephalomyelitis (ME/CFS), is a long-term, multi system disease characterised by profound, unrefreshing fatigue, pain, cognitive dysfunction, and post exertional malaise (PEM). Heart rate variability (HRV) measures the variation in time intervals between heartbeats to provide an objective indicator of autonomic nervous system (ANS) regulation and resilience. HRV tracking is used to assess autonomic dysfunction in ME/CFS and hypothesised to serve as an early warning system for predicting PEM and prioritising rest. To date there is little research on the use of continuous HRV (C-HRV) tracking, versus baseline HRV and HR monitoring as a pacing and ANS management tool.

This case reports a 63 year old female with a 7 year history of stable ME/CFS who experienced a severe symptomatic relapse following a period of physical and psychosocial stress. The patient's primary concerns were reduced functional capacity, frequent PEM and immune system flares.

Method: The subject used real time C-HRV tracking using an electrocardiogram (ECG) grade Firstbeat Life device and engaged in regular health coaching with an HRV trained coach for lifestyle support and HRV data interpretation. The aim of this study was to assess the effectiveness of C-HRV tracking with expert HRV analysis for understanding and improving ANS regulation to help manage energy, and improve functional capacity.

Results: Over the 11-week intervention, C-HRV biofeedback showed enhanced ANS regulation, increased baseline HRV, and improvements in perceived cognitive stability and energy. The patient improved her autonomic awareness, PEM predictability, identification of recovery barriers, and effectiveness of specific ANS strategies. A key finding was a lagging HRV response during immune system flares, despite immediate flu-like symptoms, which aligns with established neuroimmune models. This suggests HRV's role as an early warning system is state and system dependent, and the ANS and immune system may generate different HRV responses.

Key words: Myalgic Encephalomyelitis/Chronic Fatigue Syndrome (ME/CFS); Post exertional malaise (PEM); Heart rate variability (HRV); Autonomic nervous system (ANS); Neuroimmune lag; Pacing; Health coaching; RMSSD

Introduction

ME/CFS is mainly characterised by profound fatigue, PEM (the delayed worsening of symptoms that occurs after minimal physical or mental activity), body pain and cognitive dysfunction [1,2].

The condition also involves immune dysregulation, mitochondrial dysfunction and patients commonly show dysregulation of the ANS. This most notably involves sympathetic nervous system (SNS)

hyperactivity, which results in sleep disturbances, non-restorative sleep, and the feeling of being wired despite profound fatigue [3-6].

A typical pattern of autonomic dysfunction in ME/CFS involves an initial HRV drop and delayed recovery following physical or cognitive exertion. This lagging recovery serves as a physiological marker of PEM and the initial drop is increasingly utilised as an objective predictor of energy crashes [7-9].

ECG-grade HRV devices detect 99.95% of true heartbeats, making them significantly more accurate for clinical populations than wrist-based photoplethysmography (PPG) sensors used in commercial wearables [10-12]. Utilised in clinical research across 100+ institutions worldwide, the Firstbeat HRV tracking system synthesises continuous HR and HRV data into real time graphs and post measurement reports that map SNS and PNS activation, intensity, and physical movement [13].

The system utilises the root mean square of successive differences (RMSSD), the variance in milliseconds between consecutive heartbeats, which is the primary HRV time domain measure used to assess the activity of the PNS [14].

A higher baseline RMSSD indicates greater autonomic flexibility and nervous system resilience, whereas a lower score reflects elevated SNS dominance and reduced autonomic adaptability.
Because HRV naturally declines with age, the Firstbeat system benchmarks an individual's RMSSD against an age stratified global database of almost 600,000 measurements, providing a demographically realistic baseline rather than an arbitrary universal standard [15].

This case report explores how C-HRV tracking could be used as an objective tool for observing the state of the ANS, managing fatigue and improving wellbeing in patients with ME/CFS. By monitoring ANS changes, patients can implement data driven strategies that include pacing, sleep optimisation, task modification and autonomic regulation tools [7].

Health coaching and expert HRV analysis bridges the gap between complex HRV interpretation and the strategic implementation of lifestyle changes.

Case Presentation

The subject is a 63 year old female with a long standing history of ME/CFS. Despite her diagnosis, she had maintained a high level of stability for the previous seven years, functioning consistently at 80 - 90% of her healthy baseline. However, in 2025, a period of significant external stress triggered an acute and severe relapse.

This relapse was characterised by a range of debilitating symptoms, including severe fatigue, PEM, cognitive dysfunction and recurrent immune system flares, which lead to a persistent state of flu-like symptoms that continued for several weeks at a time. The immune flares were triggered by normal environment factors such as outdoor cold exposure and characterised by subjective fever (feeling hot without an elevated core body temperature), profound fatigue, generalised body aches, and a distinct paresthesia described by the patient as a 'buzzy' or 'static' sensation throughout the body.

The relapse resulted in a reduction of functional capacity for activities of daily living (ADLs), rendering her home bound with significantly reduced work capacity. At the time of the initial assessment, she had zero exercise tolerance, was confined to home, and only able to manage minimal household chores. The immune system flares had reduced in duration from weeks to days at a time, however her functional capacity had only minimally increased.

Written informed consent was obtained from the patient for the publication of this case report and any accompanying data.

Method - The Intervention

The patient engaged in an 11 week intervention using Firstbeat Life professional ECG grade C-HRV tracking technology, health coaching and HRV expert support to facilitate data interpretation and the implementation of targeted illness management strategies.

Firstbeat HRV Tracking

The participant wore the Firstbeat C-HRV monitor throughout the intervention period, taking daily 24 hour measurements.

The data was synthesised into daily visual graphs (Figure *1*). Sympathetic nervous system (SNS) stress reactions are depicted by red vertical bars, while parasympathetic nervous system (PNS) recovery is represented in green, and physical movement is highlighted in blue with the height of the colored bars indicating the intensity of each reaction. Heart rate (beats per minute) is represented by the solid black line mapped to the left vertical axis, and continuous HRV (milliseconds) is shown by the grey line mapped to the right vertical axis. Patient-logged daily activities are annotated along the horizontal time axis.

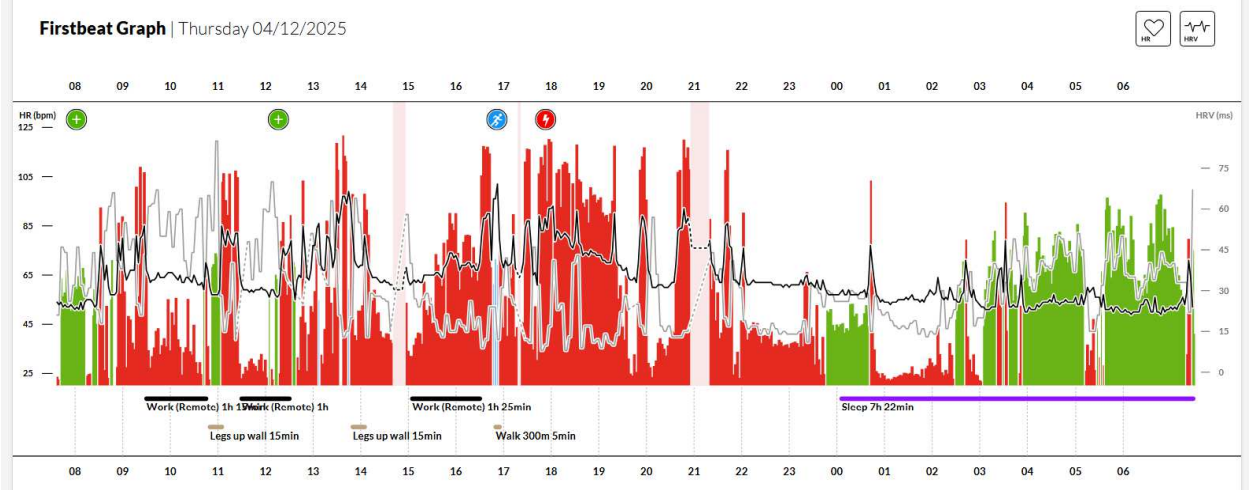


Figure 1: Example of Firstbeat C-HRV tracking profile over a 24-hour period illustrating daily autonomic stress and recovery dynamics.

Continuous heart rate variability (C-HRV) profile showing sympathetic stress (red bars), parasympathetic recovery (green bars), and physical activity (blue bars), with bar height indicating physiological intensity. Heart rate (HR, black line, left axis, bpm) and HRV (grey line, right axis, ms) are plotted against patient logged daily activities along the horizontal time axis.

Within the first few days of wear, the system establishes the user's personal physiological 'ceiling and floor' by identifying her minimum resting heart rate (HR) and maximum HRV during deep sleep. Daily scores are then weighted against this personal baseline, and updated as more data is accumulated, to reflect true deviations in nervous system health and wellbeing.

The patient's baseline HRV (RMSSD) was calculated using an average of nightly sleep readings over a seven day period during the first week of tracking and then compared against the final seven days of the 11 week intervention.

Firstbeat stress and recovery, and sleep scores are calculated by tracking high and low patterns of HRV to measure the balance between sympathetic nervous system strain (physical, mental, or environmental stress) and parasympathetic recovery. The sleep score specifically evaluates sleep duration, the depth of rest, nightly consistency, and delayed recovery during sleep. Measuring delayed sleep recovery is especially crucial, as a delayed transition into a parasympathetic state during the initial hours of sleep can significantly lower the overall quality of physiological recovery [16,17].

Wellbeing data was collected via a subjective Firstbeat Wellbeing survey, before, during and after the 11 week intervention.

Lifestyle Changes

The patient monitored daily C-HRV metrics and maintained an activity log to track real time SNS and PNS dynamics. The patient's daily tasks, routine and rest periods were adjusted in response to the daily measurement scores and real time ANS feedback.

While doing so she used a broad framework of established recovery protocols including pacing, sleep optimisation, and task modification along with ANS regulation activities to balance stress and recovery, manage energy and prevent PEM.

Real time HRV data was used to identify which ANS strategies were most effective for her unique physiological needs at that point in time. When the data indicated a state of prolonged sympathetic activity, seen as periods of ‘red’ activity or a lack of ‘green’ recovery in the real time C-HRV graph, the patient applied targeted ANS strategies to manually shift the ANS back into a parasympathetic state.

HRV Specialist Data Interpretation

To ensure the efficacy of the clinical use of the data, all tracking metrics were monitored and analysed by an HRV specialist. The specialist provided advanced data interpretation beyond the automated app analytics, identifying short and long term physiological trends, baseline shifts, and subtle variations in autonomic balance. This specialised oversight delivered with a health coaching approach provided essential guidance for the translation of data into real world practical lifestyle adjustments.

Health Coaching

Health coaching provided active listening, validation, and self-reflection to help the patient to connect her daily choices directly to her HRV data and wellbeing trends, set strategic goals, and implement sustainable lifestyle changes. This utilised a flexible, relationship first approach tailored to the patient’s fluctuating energy boundaries. Rather than adhering to a rigid, pre-scheduled timeline, coaching was conducted on an as needed basis using text messages and emails with occasional real time video calls, to minimise any impact of over exertion.

The first 2 months involved weekly message exchanges, while the patient gained knowledge and understanding of the C-HRV tracking system. This was complemented by two structured video consultations over the 11 week intervention.

Results

After 11 weeks of C-HRV data-driven management, significant physiological and subjective improvements were recorded (Table *1*). The patient demonstrated a higher baseline HRV, indicating improved ANS resilience. Subjective wellbeing scores increased across sleep quality, daytime recovery breaks, energy levels, and an overall feeling of wellness. While relative percentage changes were substantial (e.g., doubling the stress and recovery balance score), and raw values reflect an initial shift away from a critical baseline, the patient remains significantly impaired overall.

Metric	**Baseline (Month 1)**	**Progress (11 weeks)**	**Increase (%)**
Baseline HRV (RMSSD in ms)	24 ms	33 ms	+37.5%
Sleep Quality Score	37 / 100	56 / 100	+51.4%
Stress and Recovery Balance Score	23 / 100	48 / 100	+108.7%
Subjective Wellbeing	24%	34%	+41.7%

Table 1: Firstbeat HRV metrics and subjective wellbeing scores captured pre and post intervention with percentage changes

By week 11, real-time data confirmed an increased frequency and efficiency in transitioning into a PNS state. The patient displayed greater autonomic flexibility throughout the day, successfully maintaining a PNS "green" state during low stimulation activities such as light internet use or television.

Real time C-HRV tracking identified several highly effective ANS regulation techniques: Postural drainage - Leg elevation for 10 to 15 minutes up to five times daily assisted venous return; Thermal stress regulation by applying a cooling vest or chest ice packs during peak afternoon heat, or resting outdoors in the shade, successfully lowered sympathetic activity; and vagal nerve stimulation using transcutaneous electrical nerve stimulation, titrated from 2 to 10 minutes in the evening, directly supported a shift into a PNS state.

Tracking revealed the efficacy of strategies was both time and state dependent. The patient consistently achieved morning PNS activation, whereas the same strategies were ineffective in the afternoon and

evening. Real-time graphs also demonstrated that print reading upon waking promoted a PNS state, whereas electronic screen exposure triggered a sympathetic (SNS) response. To leverage morning autonomic responsiveness, the patient read print books for one hour upon waking, establishing a physiological recovery buffer before daily stressors accumulated. While standalone techniques were effective under moderate stress, combining methods proved more effective during periods of high sympathetic arousal. At the beginning of the study, interventions such as meditation, relaxation audios, and humming failed to induce a PNS response. However, following the 11-week intervention, these same strategies successfully elicited PNS activation, indicating improved baseline ANS stability.

Thermoregulation emerged as a critical barrier to recovery. Monitoring revealed a strong inverse correlation between ambient temperature and nocturnal PNS recovery. During the summer months, elevated temperatures hindered the shift into a PNS state. As the weather started to cool, despite the patient's subjective preference for warmth at night, the data revealed that over insulation (using an extra blanket) completely suppressed nightly PNS recovery. As illustrated in Figure *2*, removing the blanket after 4:00 AM subsequently shifted the patient into a PNS recovery state.

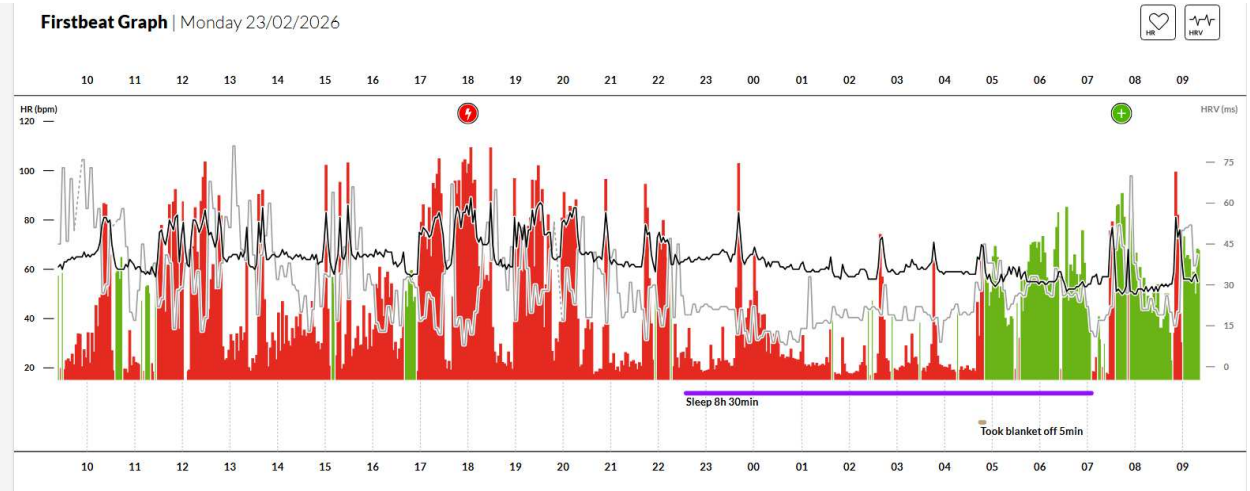


Figure 2: Figure 2: Firstbeat continuous HRV tracking graph over 24 hours depicting the impact of thermoregulation on nocturnal parasympathetic recovery.

Continuous heart rate variability (C-HRV) profile showing sympathetic stress (red bars), parasympathetic recovery (green bars), and physical activity (blue bars), with bar height indicating physiological intensity. Heart rate (HR, black line, left axis, bpm) and HRV (grey line, right axis, ms) are plotted against patient logged daily activities along the horizontal time axis.

C-HRV metrics were also used to evaluate pharmacological and supplement trials. A 10-day trial of low dose naltrexone resulted in a sharp drop in overall HRV and a near-total absence of nocturnal PNS recovery, which was resolved upon discontinuation. Similarly, on three separate trials, nightly

administration of palmitoylethanolamide correlated with a complete lack of PNS recovery during sleep and diminished HRV scores during the following days.

The Neuroimmune Lag

A central finding of this study was the detection of a distinct neuroimmune lag during immune flares, contrasting with the immediate HRV drops observed prior to exertion induced PEM. Immediately after the formal 11-week intervention, the patient experienced a severe immune flare. Despite the sudden onset of flu-like physical symptoms, C-HRV data showed a deceptively high HRV for several days, followed by a significant decline over 48 hours later. This delayed HRV drop was also observed during subsequent minor immune flares and a viral common cold.

Recognising this delayed HRV response enabled the patient to clinically differentiate between nervous system driven PEM and neuroimmune mediated crashes, prompting further investigation into the inflammatory underpinnings of her flares.

Combining C-HRV tracking with symptom monitoring subsequently allowed for more precise pacing, mitigating further relapses and supporting a gradual increase in functional capacity for activities of daily living (ADLs).

Patient Observations

C-HRV biofeedback and specialised data interpretation significantly enhanced the patient's self-efficacy and pacing accuracy. Rather than relying on subjective symptom perception alone, the patient adjusted daily tasks based on objective recovery scores, reducing the guesswork of predicting energy declinses. Over time, objective data validation fostered an intuitive autonomic awareness, allowing the patient to recognise recovery boundaries independent of HRV tracking.

The patient noted: "*Seeing the data provided the evidence I needed to trust the process, especially on the days I didn't feel well yet. It reduced the guesswork."*

Discussion

This case illustrates the potential value of utilising quantitative C-HRV data to monitor the autonomic nervous system, validate recovery strategies and increase confidence and the ability for patients with complex chronic illness to manage their daily activities.

The use of daily C-HRV tracking for chronic conditions like ME/CFS, enables the observation of delayed recovery after physical or cognitive exertion and captures real time changes in autonomic stability that one off HRV readings would not show

.

Neuroimmune Lag

The delayed HRV decline during the patient's immune system flares, contrasts with the predictive HRV drop that typically precedes PEM in patients with ME/CFS. This presentation aligns with documented delays between cardiac HRV shifts and innate immune activation, as well as the temporary protective effects of the cholinergic anti-inflammatory pathway [18,19].

This observation provides critical insight into the distinct pathophysiological pathways governing immune driven relapses versus activity induced PEM in ME/CFS. While exertion induced PEM causes an immediate drop in parasympathetic tone, immune related flares appear to elicit a delayed cardiac and ANS response.

During the acute onset of an immune flare, activation of the innate immune response causes localised peripheral cytokine release, triggering flu-like symptoms well before systemic neuroendocrine signaling alters cardiac and HRV activity. [18] In response, the nervous system engages the cholinergic anti-inflammatory pathway to counter this peripheral inflammation. Efferent signals transmitted via the vagus nerve release acetylcholine (ACh), which binds to alpha 7-nicotinic acetylcholine receptors on local tissue macrophages, actively suppressing local pro-inflammatory cytokine release without directly altering short term HRV metrics. [19] Furthermore, initial vagal reflex compensation may temporarily preserve or elevate vagal tone, producing deceptively normal RMSSD values in a central effort to suppress peripheral inflammation. [19] As inflammatory signaling eventually overwhelms central autonomic control centers in the brainstem, systemic vagal withdrawal occurs, producing the delayed HRV decline observed 48 hours post-onset [18,19].

From a diagnostic perspective, these findings indicate that cardiac HRV metrics are state dependent and may not serve as an universal early warning system for all fatigue episodes in patients with ME/CFS. Recognising whether an impending crash is driven by physical or mental exertion or inflammatory signaling is paramount for refining pacing protocols.

Specialised HRV Data Interpretation

C-HRV tracking alongside symptom and activity tracking in complex chronic illness generates dense datasets that can be challenging to interpret. While these patients may understand necessary lifestyle modifications, the diversity and irregularity of multi system dysfunction that impacts the data can create challenges with sustainably implementing changes or evaluating intervention efficacy.

Expert data analysis plays a crucial clinical role in translating complex physiological metrics into actionable management strategies, enabling patients to transition from reactive symptom management to data informed pacing while developing an intuitive awareness of her ANS boundaries.

Autonomic Stabilisation

A notable finding in this case was the evolution of the effectiveness of ANS regulation strategies over time. At baseline some ANS regulation tools failed to elicit a measurable parasympathetic response, however following 11 weeks of structured C-HRV management, these identical strategies consistently induced PNS activation.

We hypothesise that a threshold of ANS stabilisation may be required for ANS regulation strategies to produce an effective response in some patients. In cases of higher sympathetic dominance, elevated sympathetic tone may override subtle sensory or vagal inputs. In this case as baseline autonomic resilience improves (reflected by the 37.5% increase in baseline RMSSD), the nervous system establishes sufficient physiological flexibility to respond to targeted parasympathetic interventions.

Limitations

Several limitations should be considered when interpreting these findings. As a single case (N=1) study, these findings may not be representative of the broader ME/CFS population or account for varying degrees of illness severity.

Additionally, the data suggests a correlation between C-HRV guided interventions and increased functionality. The absence of a controlled environment means that external variables, such as additional lifestyle changes cannot be entirely ruled out as contributing factors to the physiological shifts observed.

The subjective wellbeing measurement tool was used as a mandatory part of the Firstbeat system, however this is not a validated patient reported outcome measure and has not been independently validated for ME/CFS populations.

Although ECG derived HRV measurements represent the highest standard for signal acquisition, monitoring may be constrained by artefact related inaccuracies and limitations can exist in the interpretation of HRV when collected continuously in real world conditions. Even though changes in HRV can be attributed to a number of causes, detailed journaling within the C-HRV tracking app in this study improves the interpretation of data, identification of trends with relation to autonomic nervous system changes.

Conclusion

This case study demonstrates that continuous HRV tracking, paired with expertise in data interpretation and health coaching, can offer a dynamic framework for identifying effective ANS regulation strategies and managing complex chronic conditions like ME/CFS. It may facilitate a deeper physiological understanding and a potentially more efficient recovery trajectory than utilising established recovery protocols alone.

Critically, these findings suggest that HRV's role as an early warning system may be state dependent, acting as a predictor of exertion induced PEM, but as a delayed, lagging indicator of immune driven relapses due to neuroimmune lag mechanics. Furthermore, the data suggests that a foundational threshold of autonomic stability may be required before some ANS regulation strategies become effective. While continuous HRV tracking holds strong potential to bridge the gap between subjective symptoms and physiological reality, further controlled research is needed to validate these insights across broader clinical cohorts.

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Appendices

Table 2: Firstbeat baseline HRV data, sleep, and stress and recovery scores with 7 day averages pre and post 11-week intervention

Baseline HRV and HRV Measures	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Average
Baseline HRV at start 7 days (numbers are averages taken from 2-3 day nightly measurements)*		22		22			27	**24**
Baseline HRV last 7 days in 11 weeks (HRV measured each night)	29	36	36	33	33	29	32	**33**
Sleep Scores (out of 100) first 7 days *		43		13			46	**34**
Sleep Scores (out of 100) last 7 days	58	51	58	57	57	56	53	**56**
Stress and Recovery Balance Scores (out of 100) first 7 days *		36		17			16	**23**
Stress and Recovery Balance Scores (out of 100) last 7 days	46	51	57	51	46	44	41	**48**

* measurements were taken every 2-3 days at the beginning of the intervention and the average of these measurements is recorded on day 2, 4 and 7

Table 3: Firstbeat app recorded subjective wellbeing scores pre and post intervention

Question (1-5 Completely disagree - Completely agree)	Week 1	%	Week 11	%	Difference	Increase
1) I feel that I sleep enough.	2	40	4	80	40	100%
5) I don't feel stressed.	4	80	4	80	0	0%
6) My days include breaks and time for recovery.	4	80	5	100	20	25%
7) I feel alert and energetic most of the time.	1	20	2	40	40	100%
10) I feel well at the moment.	1	20	2	40	60	100%

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- CaseReportTable2.jpeg
- CaseReportTable3.jpeg