



Mobile Heart Rate Variability Biofeedback for Work-Related Stress in Employees and the Influence of Instruction Format (Digital or Live) on Training Outcome: A Non-Randomized Controlled Trial

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Abstract

Work-related stress is a major health issue in most industrialized countries. Heart rate variability biofeedback (HRV-BfB) can promote resilience and stress coping capacity. Mobile HRV-BfB could contribute to stress prevention in the workplace. Little is known about whether the type of training, with digital or live instruction, has an impact on the training outcome. This study analyzes the psychophysiological effects of four-week workplace resilience training with mobile HRV-BfB and the influence of instruction format (digital or live) on training success. This was a prospective, three-arm, non-randomized controlled trial with parallel group design. 73 employees of a bearing and seal manufacturer (58.9% male, 86.3% full-time employment, 67.1% office workers) attended resilience training with HRV-BfB, live ($n=24$) or digital ($n=19$) format, or served as waitlist controls ($n=30$). HRV-BfB training spanned four weeks. Participants applied resilience techniques to increase HRV using visual biofeedback. Data were collected at baseline (T0), post-intervention (T1), and another four weeks later (T2). Primary outcome measure was the Burnout scale of the Copenhagen Psychosocial Questionnaire (COPSOQ) at T1. Secondary outcome measures included further COPSOQ scales, self-reported sleep quality (Pittsburgh Sleep Quality Index, PSQI), and HRV parameters. Burnout parameters decreased significantly in HRV-BfB and waitlist. The decrease (T0-T1 and T0-T2) showed higher effect sizes in HRV-BfB (Cohen's d : 0.63; 0.69) than in waitlist (d : 0.27; 0.36). Sleep quality improved in HRV-BfB with small effect sizes (no change for waitlist). SDNN (standard deviation of beat-to-beat intervals) increased in HRV-BfB between T0 and T1 (d : 0.23;). In subgroup analysis, digital reached higher effect sizes for improvement in burnout (d : 0.87; 0.92) and sleep quality (d : 0.59; 0.64) than live learning (burnout: d : 0.43; 0.51; sleep quality: d : 0.28; 0.22). HRV-analysis revealed no differences between subgroups. Four-week mobile HRV-BfB resilience training reduced stress and burnout symptoms in employees. No significant differences were found between HRV-BfB digital or live. Hence, companies should choose the approach that fits their company profile or, if possible, offer both formats to accommodate the different needs of employees. However, findings were nonhomogeneous and should be verified by further studies.

Trial Registration: [ClinicalTrials.gov](https://clinicaltrials.gov), NCT04897165, 05/18/2021, retrospectively registered.

Keywords Work-related stress · Workplace intervention · Resilience · Heart rate variability · Biofeedback · Sleep quality

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Introduction

In recent decades, work-related stress has become a major health issue in most industrialized countries due to transforming working conditions (Sutarto et al., 2012; Weber et al., 2019). According to the job demands-resources model (JDR), stress results from an imbalance between high job demands (e.g., physical, mental and emotional efforts or work overload) and minor job resources (e.g., support, autonomy, and feedback) (Mistretta et al., 2018; Rabe et al., 2012; Weber et al., 2019).

The peripheral nervous system responds to stress stimuli by activating the hypothalamic-pituitary-adrenal axis (HPA) and the autonomic nervous system (ANS) (Crameri et al., 2020). The ANS is the first-responder to stress and facilitates adaptive stress responses to rebalance physiological homeostasis (Chrousos, 2009; Crameri et al., 2020). Mild stress is not inherently maladaptive or harmful (Chandola et al., 2010; De Witte et al., 2019). However, excessive or prolonged stress leads to persistent stress response activation, posing significant health risks if recovery is inadequate (Chandola et al., 2010; De Witte et al., 2019). Chandola et al. described an association between work-related stress and elevated stress response in terms of HPA (e.g., higher cortisol awakening response, CAR) and ANS biomarkers (increased catecholamine levels and decreased heart rate variability, HRV) (Chandola et al., 2010).

HRV is a measure of variation in time intervals between successive heartbeats (inter-beat intervals) (Dong et al., 2018; Tinello et al., 2022) that indicates self-regulation capacity (Goessl et al., 2017; Lehrer et al., 2020). High HRV has been linked to greater resilience (An et al., 2020; Lalanza et al., 2023; Lehrer & Gevirtz, 2014), improved cognitive performance (Crameri et al., 2020), and lower cardiovascular risk (Brinkmann et al., 2020). Low HRV is associated with autonomic rigidity and reduced arousal control, which promotes stress-related diseases (e.g., cardiovascular or musculoskeletal disorders) (An et al., 2020; Chandola et al., 2010; Kristensen et al., 2005) and mental disorders such as depression or burnout (Economides et al., 2020; Mistretta et al., 2018; Weber et al., 2019).

Hence, unmanaged stress can impair physical and mental performance (Mistretta et al., 2018; Weber et al., 2019), resulting in high economic costs due to absenteeism, employee turnover and higher accident rates (De Witte et al., 2019; Marcatto et al., 2016; Roy et al., 2023; Weber et al., 2019). To mitigate the negative effects of work-related stress (Jensen et al., 2022; Robertson et al., 2015), work-based interventions have been developed to strengthen employee resilience (Hsieh et al., 2020; Mistretta et al., 2018). Heart rate variability biofeedback (HRV-BfB) improves self-regulation by increasing HRV through

breath training (Hsieh et al., 2020; Lin et al., 2023; Robertson et al., 2015). Breathing at resonance frequency (typically 4.5 to 6.5 breaths per minute) strengthens the vagus nerve, stimulates respiratory sinus arrhythmia (RSA) and the baroreflex (BR) (Lehrer et al., 2020), and thus improves autonomic homeostasis, cardiovascular stability and emotion regulation (Lehrer & Gevirtz, 2014; Sutarto et al., 2012). Hence, HRV-BfB can promote resilience by enhancing bodily stress tolerance, regeneration, and adaptability to physical, mental, and environmental demands (An et al., 2020; Hsieh et al., 2020; Lehrer et al., 2020; Nashiro et al., 2023a, b).

Preventive workplace interventions are often expensive and unsuitable for daily work routines (Sutarto et al., 2012). Furthermore, most companies prefer reactive interventions instead of prevention programs (Weber et al., 2019). Thus, 40% of employees in the European Union report inadequate management of stress in their workplace (Marcatto et al., 2016). Mobile-delivered HRV-BfB is time and cost effective, readily accessible, and easier to implement than in-person interventions (Hsieh et al., 2020; Mistretta et al., 2018). However, it remains an open question whether a digital intervention (mobile HRV-BfB with digital instruction) is as effective for resilience and stress parameters as a live intervention (mobile HRV-BfB with in-person instruction).

The present study analyzes the effect of four-week resilience training with mobile HRV-BfB on stress parameters in employees. The participants performed autonomous training with a biofeedback device accompanied by three instruction sessions. To examine the potential impact of the instruction format on training outcome, one group attended digital lessons (hereafter referred to as “digital”), while the other attended in-person instruction (“live”).

Methods

Trial Design

This was a prospective, three-arm, non-randomized, controlled parallel group trial with an experimental and a wait-list control condition (allocation ratio 2:1, $n = 30$ per group). We examined the effects of four-week resilience training with mobile HRV-BfB on psychophysiological parameters in employees of a bearing and seal manufacturer at its German headquarters. Participants in the experimental condition performed resilience training with mobile HRV-BfB based on digital or live instruction. The trial was conducted between October and December 2016. The Ethics Committee of the Medical Association of Baden-Württemberg in Stuttgart, Germany, gave ethical approval (approval number:

F-2016-091). Written informed consent was obtained from all participants.

Participants

Participants were recruited through an information session at the company, notices in the company's internal communication system, and referral during routine examinations by the company physician. Employees of at least 18 years of age were eligible to participate. Exclusion criteria were a cardiac pacemaker, physician-diagnosed heart failure or arrhythmia, and physician-prescribed cardiac medication (e.g., beta-blockers, diuretics, ACE inhibitors, calcium channel blockers, or antiarrhythmic agents). Eligible participants provided information on gender, age, body mass index (BMI) and occupation (field and type of work, weekly working hours). Participants who worked in the company's field service were assigned to HRV-BfB digital. The inhouse staff were assigned to HRV-BfB live or waitlist control group by drawing a sealed envelope. The waitlist control group also included participants who could not attend one of the experimental groups for scheduling reasons (e.g. absence from work during the study period). It was agreed with the waitlist participants that they would receive the resilience training after completion of the study.

Interventions

The two experimental groups performed mobile HRV-BfB resilience training autonomously for four weeks, accompanied by regular instructional sessions. The live group attended three live instructional sessions at the company (90 min each) at the beginning of the first, third, and fourth

week. The digital group had access (by e-mail) to three digital instructional modules (60 min each) at the same time-points. Both instructional approaches provided theoretical background on resilience, HRV, and stress, explained handling of the HRV-BfB device, and taught three resilience techniques: heart-focused breathing, deep breathing, and the Quick Coherence® Technique (HeartMath Deutschland GmbH, Saarbrücken, Germany) (Table 1). During the four-week training period, both groups were to practice independently with Inner Balance™ Trainer software (HeartMath Deutschland GmbH, Saarbrücken, Germany) three times daily for 5 min at work and in their free time. During exercise, RSA was measured using ear clip sensors that detected heart rate and inter-beat intervals. Participants performed the learned resilience techniques as well as breath training under the guidance of the software's visual feedback to increase HRV, learning to self-regulate their stress response (Robertson et al., 2015). A minimum training period of two weeks was prerequisite for inclusion in the primary analysis (per-protocol principle). Waitlist participants received the same training after study completion.

Outcome Measures

Questionnaire data were collected at baseline (pre-intervention, T0), after the four-week training (post-intervention, T1), and another four weeks later (follow-up, T2, Fig. 1). HRV data of the first and last three training sessions were averaged to obtain pre- (T0) and post-intervention (T1) values.

The Copenhagen Psychosocial Questionnaire (COPSOQ) is a validated instrument to assess psychosocial workload and strain (Kristensen et al., 2005; Nubling et al., 2006). We

Table 1 Course outline for digital and live instruction

Module	Topic
Module 1: “Introduction”	● Core concepts and scientific background of resilience, heart rate variability (HRV), physical stress response and biofeedback (BfB). ● Use of the HRV-BfB sensor and software. ● Instruction on how to apply the resilience techniques deep breathing and heart-focused breathing: 1. Deep breathing: “Breathe deeper and slower than usual to the beat of the clock, with inhalations and exhalations of equal duration.” For the pacer, participants could choose a clock rhythm between 8 and 12 s per breathing cycle. 2. Heart-focused breathing: “Direct your attention to the heart area and imagine your breath flowing in and out through your heart. Breathe a little more deeply than usual (inhale and exhale for about 5–6 s each).”
Module 2: “Deepening”	● Deepening of the theoretical basis of module 1. ● Positive emotions and stress regulation. ● Instruction on how to apply the Quick Coherence® Technique: - Part 1: Heart-focused breathing (see module 1). - Part 2: “Activate positive feelings such as appreciation or care for someone or something in your life. Suggestion: try to consciously experience the emotion you feel for someone you love, or for a pet, or a special place; or experience tranquility and serenity.”
Module 3: “Internalization”	● Review and summary of the resilience techniques learnt. Explanation of how to continue using the techniques without the HRV-BfB device. ● Resilience strategies for daily life. ● Action plans for daily life to improve resilience skills.

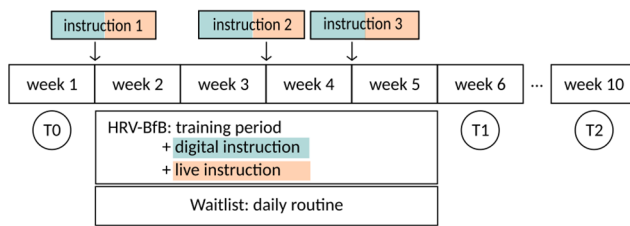


Fig. 1 Timeline (HRV-BfB = heart rate variability biofeedback)

used five scales of the adapted German long version (141 questions): personal burnout (6 questions, derived from the Copenhagen Burnout Inventory), subjective general health (1 question, derived from the European Quality of Life 5 Dimensions, EQ-5D), work-privacy conflict (5 questions, according to Netemeyer and colleagues) (Netemeyer et al., 1996), behavioral stress symptoms (8 questions), and cognitive stress symptoms (4 questions) (Nubling et al., 2006). The majority of questions are answered on five-point ordinal scales (Nubling et al., 2006). Answers were transformed to a value ranging between 0 = minimum value (e.g., “do not agree at all”) and 100 = maximum value (e.g., “fully agree”) and were averaged to scale scores (0–100) (Nubling et al., 2006). At baseline, participants also rated their current work performance relative to their best possible performance (scale 0 to 10, high = positive) and in terms of mental and physical job demands (scale 1 to 5, low = positive) using three individual COPSOQ questions (B.16, B.17a, B.17b).

The Pittsburgh Sleep Quality Index (PSQI) is a validated (Cronbach’s $\alpha = 0.83$), 19-item questionnaire assessing sleep quality and sleep disturbance over the past four weeks (Buysse et al., 1989). Items can be averaged into component scores of subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbance, daytime dysfunction, and use of sleep medication (range 0–3, higher scores indicate poorer sleep) (Buysse et al., 1989). In the present study, the items for the component scores of subjective sleep quality, sleep latency, and sleep duration were evaluated.

In the HRV-BfB condition, HRV was measured by the BfB device during training. Data were recorded by Inner Balance™ Trainer software and analyzed with HRV-Scanner software (BioSign GmbH, Ottenhofen, Germany). The signal underwent automated t-wave detection. Inter-beat intervals were analyzed for SDNN (standard deviation of inter-beat intervals, in ms), RMSSD (root mean square of successive differences, in ms), and pNN50 (percentage of interbeat intervals that differ by more than 50 ms, in %). Baevsky’s stress index was computed from the inter-beat intervals histogram’s main characteristics (mode value, mode amplitude, and variation range; higher values indicate higher sympathetic activity) (Baevsky & Chernikova, 2017). HRV was not tracked for the control group because

we did not have the financial resources to equip this group with BfB devices as well. Therefore, we had to do without HRV measurement in the control group, which is mentioned as a limitation in the discussion section.

At T1, HRV-BfB participants rated training success, integration of the training into professional and private life, and the attention they received for their questions and needs during the intervention (hereafter referred to as “support”) on a five-point scale (1–5, low = positive) and in free text, and indicated whether they would choose the same instruction format again (digital or live). At T2, they were asked about their motivation to continue using the learned resilience techniques after completion of the study, even without the HRV-BfB device.

Primary and Secondary Outcome Measures

Primary outcome measure was COPSOQ personal burnout at T1. Secondary outcome measures included COPSOQ scales personal burnout (at T2), general health, work-privacy conflict, behavioral stress symptoms, and cognitive stress symptoms (T1 and T2), PSQI component scores sleep quality, sleep latency, and sleep duration (T1 and T2), and HRV parameters of heart rate, SDNN, RMSSD, pNN50, and stress index (at T1 and T2) as well as the evaluation of training success, integration into professional and private life and support (at T1).

Sample Size

We found no other studies on the effects of HRV-BfB resilience training in employees considering the instruction format (digital or live), and estimated that a convenience sample of 90 participants would be sufficient for an initial evaluation.

Statistical Analysis

Statistical analyses were performed with R (R Core Team, 2022) running in RStudio (RStudio Team, 2022). The proportion of missing values was small (COPSOQ: 1.37%, PSQI: 1.52%, HRV: 17.23%). They were replaced using a single imputation based on predictive mean matching (R package: mice (van Buuren & Groothuis-Oudshoorn, 2011)). We generated 40 imputed datasets and averaged them to obtain single imputation values. A p -value below 0.05 (two-tailed) was considered to indicate statistical significance. The primary outcome measure was analyzed with a linear model, with condition (HRV-BfB or waitlist) as the factor and baseline personal burnout (T0) as a covariate. Cohen’s d effect sizes (d_{adj}) were calculated using the covariate adjusted means (M_{adj} , R package: effects) (Fox, 2003).

Sensitivity analysis was conducted to compare the results of the per-protocol-based primary analysis with an intention-to-treat-based analysis. Secondary outcome measures were analyzed descriptively with mean differences, 95% confidence intervals (CI) and Cohen's d effect sizes (R package: *effsize*) (Torchiano, 2020) for the comparison between both conditions at the three timepoints (called *between*-analysis) as well as for the changes between timepoints within each condition (called *within*-analysis). Free-text data were summarized qualitatively. Baseline characteristics of the HRV-BfB and waitlist participants were compared with Welch's t -test for continuous variables and Pearson's Chi-squared test or Fisher's exact test for categorical variables. Ancillary analyses included a descriptive subgroup analysis to compare the results of secondary analysis between HRV-BfB digital and live.

Results

Study Population

Ninety individuals registered to participate (HRV-BfB: $n=60$, waitlist: $n=30$). Three (HRV-BfB: $n=1$, waitlist: $n=2$) did not complete the questionnaires at T2 and were lost to follow-up. Seventeen HRV-BfB participants were excluded from the primary analysis (Fig. 2). The final sample ($n=73$) was predominantly male (58.9%), 45 to 54 years old (53.4%), and employed full-time (at least 35 h/week, 86.3%). Fields of work included office (67.1%), manufacturing (11.0%), and sales force (8.2%, other fields: 13.7%). Baseline characteristics were similar between HRV-BfB and waitlist, except for age distribution (Table 2).

Training Adherence

In HRV-BfB, 28.3% ($n=17$) of participants (digital: $n=11$, live: $n=6$) were excluded from primary analysis due to poor training adherence (less than two weeks, $M=1.1 \pm 0.6$

weeks). Exclusion rate was higher in digital (36.7%, $n=11$, mean training period $M=0.8 \pm 0.5$ weeks) than in live (20.0%, $n=6$, $M=1.5 \pm 0.4$ weeks). The excluded participants were significantly younger ($p=0.02$), had significantly higher stress levels (behavior-related stress symptoms: $p<0.01$, cognitive stress symptoms: $p<0.01$), higher personal burnout scores ($p=0.01$) and poorer PSQI scores for subjective sleep quality ($p=0.03$). The included participants ($n=43$) had a mean training period of 3.6 ± 0.6 weeks (digital: $M=3.6 \pm 0.6$, live: $M=3.6 \pm 0.6$), with 2.7 training sessions per day (digital: $\bar{O}=2.9$, live: $\bar{O}=2.6$), mean duration 5.7 ± 2.8 min each (digital: $M=5.5 \pm 2.4$, live: $M=5.7 \pm 3.0$). Main training times were before bed (72.1%), after work (65.1%), after waking up (60.5%), after lunch (50.0%), and after stressful situations (18.6%). Heart-focused breathing was applied most frequently (deep breathing: 25.6%, Quick Coherence® Technique: 16.3%). 79.1% ($n=34$) attended all three instruction modules, with a higher participation rate in digital (94.7%, $n=18$; live: 66.7%, $n=16$).

Outcomes and Estimation

Primary Outcome Measure: COPSOQ Personal Burnout at T1

The primary analysis revealed no significant difference between HRV-BfB ($M_{adj}=39.19 \pm 12.52$) and waitlist ($M_{adj}=44.10 \pm 12.56$) for personal burnout at T1 [$F(1,70)=0.09$, $p=0.77$, $d_{adj}=0.39$]. The sensitivity analysis (intention-to-treat-based) yielded consistent results [$F(1,87)=2.12$, $p=0.15$, $d_{adj}=0.32$]. Although the descriptive analysis showed no significant *between*-differences at the three timepoints (Table 3), the *within*-decreases from T0 to T1 and from T0 to T2 (Table 4) reached higher effect sizes for HRV-BfB than for the waitlist (Fig. 3A. and B.).

Ancillary analysis revealed no differences between HRV-BfB digital and live (Table 5). Personal burnout decreased significantly in both groups (Table 6), but digital achieved higher effect sizes for *within*-reductions (T0-T1 and T0-T2, Fig. 4A. and B.).

Secondary Outcome Measures: COPSOQ Scales

Descriptive analysis revealed no significant differences between HRV-BfB and waitlist at all three timepoints (Table 3). However, significant improvement was found on all COPSOQ scales between T0 and T1 in HRV-BfB but not in the waitlist (Table 4). In *within*-group comparisons between T0 and T2, analyses revealed significant improvement for Behavioral Stress Symptoms scale in both conditions (effect size higher for HRV-BfB, Fig. 3A. and B.), and significant improvement on the Cognitive Stress

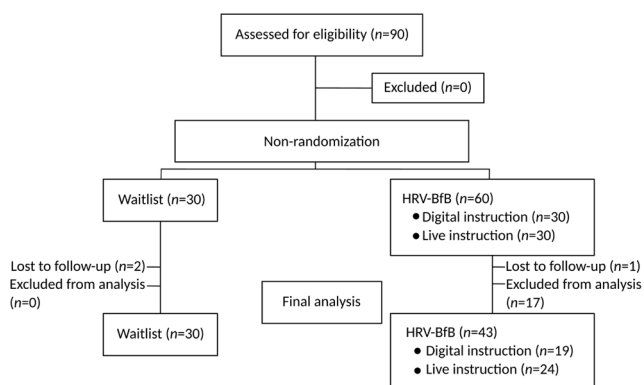


Fig. 2 Participant flow (HRV-BfB = heart rate variability biofeedback)

Table 2 Baseline characteristics

		HRV-BfB (<i>n</i> = 43)	Waitlist (<i>n</i> = 30)	<i>p</i> -value
Demographics				
Gender, <i>n</i> (%)	Female	14 (32.6)	14 (46.7)	0.14 [†]
	Male	29 (67.4)	14 (46.7)	
	No answer	0 (0.0)	2 (6.7)	
Age, <i>n</i> (%)	25–34 years	7 (16.3)	2 (6.7)	< 0.01 [†]
	35–44 years	12 (27.9)	1 (3.3)	
	45–54 years	17 (39.5)	22 (73.3)	
	> 55 years	7 (16.3)	5 (16.7)	
BMI (kg/m ²)		25.0 ± 3.4	26.4 ± 2.8	0.057 [‡]
Job Description				
Field of work, <i>n</i> (%)	Office	30 (69.8)	19 (63.3)	0.09 [†]
	Manufacturing	7 (16.3)	1 (3.3)	
	Sales force	3 (7.0)	3 (10.0)	
	Other	3 (7.0)	7 (23.3)	
Type of work, <i>n</i> (%)	Mental work	36 (83.7)	21 (70.0)	0.25 [†]
	Physical work	0.0	0 (0.0)	
	Both	7 (16.3)	9 (30.0)	
Weekly working hours, <i>n</i> (%)	≥ 35 h/week	38 (88.3)	25 (83.3)	0.73 [†]
	< 35 h/week	5 (11.6)	5 (16.7)	
Current work performance (COPSOQ)...	...compared to the best possible performance [0–10] ¹	7.5 ± 1.4	7.5 ± 1.3	0.97 [‡]
	...in terms of mental job demands [1–5] ²	2.3 ± 0.8	2.1 ± 0.9	0.47 [‡]
	...in terms of physical job demands [1–5] ²	1.8 ± 0.8	2.1 ± 0.7	0.16 [‡]
Psychosocial Questionnaires				
COPSOQ [0–100]	Personal burnout ²	51.7 ± 12.6	46.3 ± 19.1	0.17 [‡]
	General health ¹	69.8 ± 165.0	73.0 ± 13.9	0.36 [‡]
	Behavioral stress symptoms ²	37.8 ± 17.4	33.1 ± 21.4	0.33 [‡]
	Cognitive stress symptoms ²	42.0 ± 17.5	39.8 ± 22.3	0.56 [‡]
	Work-privacy conflict ²	47.1 ± 25.6	38.8 ± 25.1	0.17 [‡]
PSQI [0–3]	Sleep quality ²	1.3 ± 0.8	1.3 ± 0.8	0.97 [‡]
	Sleep latency ²	1.0 ± 0.9	1.3 ± 1.2	0.22 [‡]
	Sleep duration ²	0.8 ± 0.8	1.2 ± 1.1	0.10 [‡]

Notes Data are means ± SD if not otherwise indicated. ¹ high = pos., ² low = pos., [†] Pearson's Chi-squared test/Fisher's exact test, [‡] Welch's unequal variances t-test. HRV-BfB = heart rate variability biofeedback, COPSOQ = Copenhagen Psychosocial Questionnaire, PSQI = Pittsburgh Sleep Quality Index

Symptoms and Work-Privacy Conflict Scales in HRV-BfB only (Table 4).

Ancillary analysis revealed no significant differences between the two HRV-BfB groups, except for the General Health scale at T1 (higher score for digital, Table 5). *Within*-improvements were similar in both groups, but general health increased only for the digital group between T0 and T1 (Table 6).

Secondary Outcome Measures: PSQI Components

PSQI sleep quality, sleep latency and sleep duration improved significantly in HRV-BfB between T0 and T1 and T0 and T2 (no change in waitlist, Table 4; Fig. 3C. and D., Fig. 5), yielding significant differences between HRV-BfB and waitlist at T1 and T2 (Table 3).

Ancillary analysis showed no significant differences in PSQI between the two HRV-BfB groups (Table 5). However, digital reached higher effect sizes for the *within*-improvement of sleep quality (Fig. 4C. and D., Table 6).

Secondary Outcome Measures: HRV Parameters (HRV-BfB Condition)

Although mean heart rate increased, we found significant increases for SDNN between T0 and T1. No changes occurred in RMSSD, pNN50 and stress index (Table 7).

Ancillary analysis yielded no differences between digital and live learning at T1 (Table 5).

Table 3 Mean values and between-analysis for Copenhagen Psychosocial Questionnaire (COPSOQ) and Pittsburgh Sleep Quality Index (PSQI) at pre-intervention (T0), post-intervention (T1), and follow-up (T2)

	HRV-BfB (<i>n</i> = 43)			Waitlist (<i>n</i> = 30)			HRV-BfB vs. waitlist: Diff (CI); ES		
	T0	T1	T2	T0	T1	T2	T0	T1	T2
COPSOQ [0–100]									
Personal burnout ²	51.74 ± 12.57	41.57 ± 19.19	41.76 ± 16.20	46.25 ± 19.09	40.69 ± 22.34	39.25 ± 20.26	5.49 (-2.51;13.50); 0.35	0.88 (-9.18;10.93); 0.04	2.51 (-6.41;11.43); 0.14
General health ¹	69.77 ± 15.96	74.42 ± 14.69	72.72 ± 17.88	73.00 ± 13.93	70.33 ± 15.20	70.13 ± 14.87	-3.23 (-10.26;3.79); 0.21	4.09 (-3.04;11.21); 0.27	2.59 (-5.09;10.27); 0.15
Behavioral stress symptoms ²	37.79 ± 17.42	26.89 ± 16.12	27.01 ± 15.54	33.12 ± 21.41	31.04 ± 22.74	27.15 ± 21.30	4.67 (-4.81;14.14); 0.24	-4.15 (-13.85;5.55); 0.22	-0.14 (-9.29;9.01); 0.01
Cognitive stress symptoms ²	42.01 ± 17.48	30.23 ± 18.50	31.41 ± 19.45	39.17 ± 22.26	35.83 ± 20.76	35.24 ± 20.20	2.84 (-6.91;12.59); 0.15	-5.60 (-15.06;3.86); 0.29	-3.83 (-13.30;5.63); 0.19
Work-privacy conflict ²	47.09 ± 25.60	40.55 ± 25.20	35.97 ± 26.19	38.75 ± 25.13	38.54 ± 27.57	35.47 ± 22.85	8.34 (-3.69;20.38); 0.33	2.01 (-10.66;14.68); 0.08	0.49 (-11.03;12.02); 0.02
PSQI [0–3]									
Sleep quality ²	1.33 ± 0.75	1.02 ± 0.71	1.02 ± 0.74	1.33 ± 0.76	1.40 ± 0.72	1.40 ± 0.72	-0.01 (-0.37;0.35); 0.01	-0.38 (-0.72;-0.04); 0.53	-0.38 (-0.72;-0.03); 0.51
Sleep latency ²	0.98 ± 0.89	0.63 ± 0.66	0.70 ± 0.67	1.30 ± 1.21	1.33 ± 1.18	1.33 ± 1.03	-0.32 (-0.84;0.20); 0.31	-0.71 (-1.19;-0.22); 0.78	-0.64 (-1.07;-0.20); 0.76
Sleep duration ²	0.84 ± 0.78	0.63 ± 0.69	0.74 ± 0.76	1.23 ± 1.10	1.23 ± 1.07	1.23 ± 0.90	-0.40 (-0.87;0.08); 0.43	-0.61 (-1.05;-0.16); 0.70	-0.49 (-0.89;-0.09); 0.60

Notes Data are means ± SD. ¹ high = pos., ² low = pos. HRV-BfB = heart rate variability biofeedback, Diff = mean difference, CI = 95% confidence interval, ES = Cohen's *d* effect size. **Bold** indicates confidence intervals that do not contain zero.

Evaluation of the HRV-BfB Training

There were no differences between the digital and live groups in terms of training success and integration into private and professional life. Support was rated better in the live group (Table 8). Factors for training success were the autonomous induction of relaxation (named by $n=32$), improved body awareness and control ($n=7$), increased mindfulness ($n=6$), and theoretical knowledge about resilience, stress, and HRV ($n=4$). Criticism related to impact and effort ratio ($n=9$), reversion to old patterns ($n=7$), or the method itself ($n=4$). Problems with integration into professional life related to disruptive training environments ($n=14$) and lack of time due to high work demands ($n=13$). Difficulties with integration into private life were lack of time ($n=6$) or motivation ($n=4$) and role conflicts ($n=3$). All live participants would choose this approach again. However, 21.1% ($n=4$) in the digital group would, in retrospect, prefer the live format because of better personal attention ($n=3$) and interaction with other participants ($n=1$). Participants had chosen the digital format due to temporal ($n=6$) and local reasons ($n=6$) (primarily sales force employees), pre-existing HRV-BfB experience ($n=3$), or greater flexibility ($n=3$). Reasons for enrolling in live learning included personal attention ($n=12$), face-to-face instruction ($n=3$), interaction with others ($n=3$), and potentially higher motivation from fixed schedules ($n=2$). At T2, 51.2% ($n=22$; live: $n=13$, digital: $n=9$) indicated high to very high motivation to continue using the learned resilience techniques without the HRV-BfB device, 28.1% ($n=9$; live: $n=5$, digital: $n=4$) indicated medium motivation, and 25.6% ($n=11$; live: $n=6$, digital: $n=5$) indicated low motivation (no response: 2.3%, $n=1$).

Discussion

In the present study, four-week resilience training with mobile HRV-BfB improved burnout and stress symptoms, work-privacy conflict, sleep quality, and HRV parameter SDNN in employees with small to medium effect sizes. Improvement in burnout and stress symptoms also occurred in the waitlist control condition with small effect sizes. However, HRV-BfB participants achieved higher effect sizes and significant group differences were found for sleep quality, latency, and duration at T1 and T2. Ancillary analysis revealed no significant subgroup differences when comparing the digital HRV-BfB to the live learning format, but burnout symptoms and sleep quality improved with higher effect sizes in the digital group. Training adherence and rating of training success were similar in both formats.

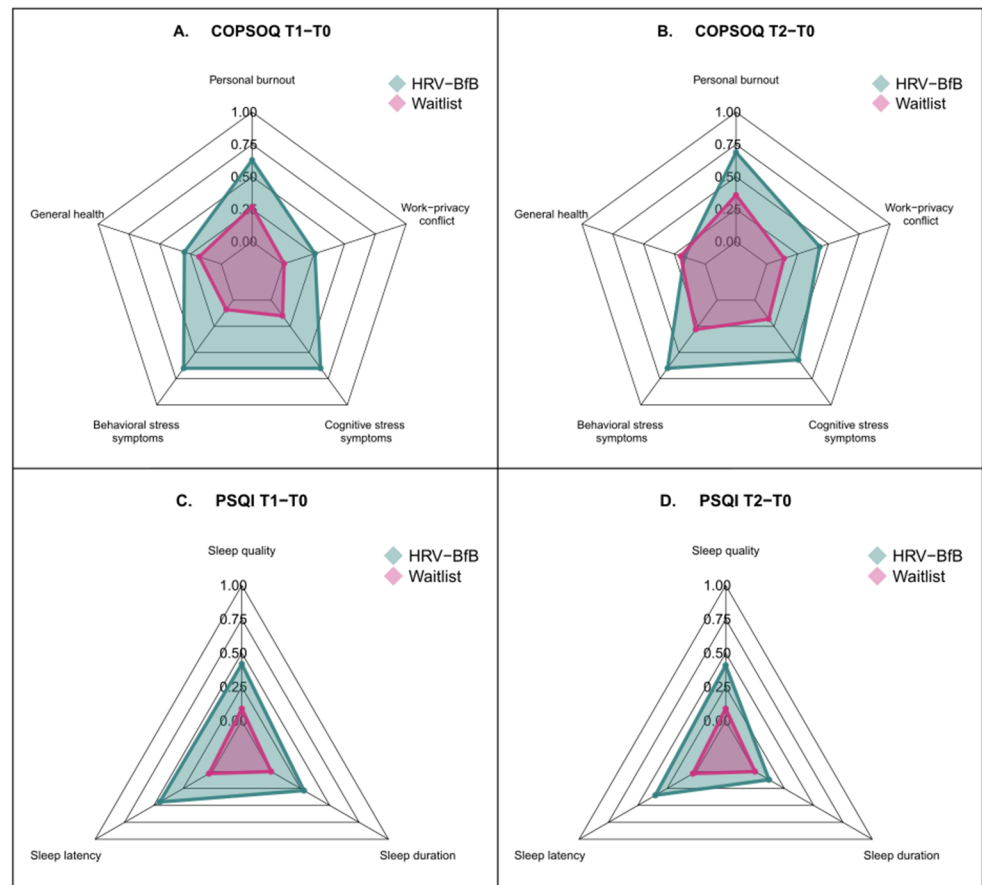
Table 4 Within-analysis for Copenhagen Psychosocial Questionnaire (COPSOQ) and Pittsburgh Sleep Quality Index (PSQI), post-intervention (T1) and follow-up (T2) versus pre-intervention (T0)

	HRV-BfB (<i>n</i> = 43)						Waitlist (<i>n</i> = 30)					
	T1 vs. T0			T2 vs. T0			T1 vs. T0			T2 vs. T0		
	Diff	CI	ES	Diff	CI	ES	Diff	CI	ES	Diff	CI	ES
COPSOQ [0–100]												
Personal burnout ²	-10.17	(-14.50;-5.85)	0.63	-9.99	(-13.44;-6.53)	0.69	-5.56	(-9.08;-2.03)	0.27	-7.00	(-11.49;-2.52)	0.36
General health ¹	4.65	(0.95;8.35)	0.30	2.95	(-1.10;7.00)	0.17	-2.67	(-7.36;2.03)	0.18	-2.87	(-7.74;2.01)	0.20
Behavioral stress symptoms ²	-10.90	(-16.09;-5.71)	0.65	-10.78	(-15.50;-6.07)	0.65	-2.08	(-6.39;2.22)	0.09	-5.97	(-10.21;-1.73)	0.28
Cognitive stress symptoms ²	-11.77	(-16.56;-6.98)	0.65	-10.60	(-15.67;-5.52)	0.57	-3.33	(-8.41;1.75)	0.15	-3.93	(-9.12;1.26)	0.18
Work-privacy conflict ²	-6.54	(-11.73;-1.35)	0.26	-11.13	(-16.25;-6.00)	0.43	-0.21	(-6.59;6.18)	0.01	-3.28	(-10.70;4.14)	0.14
PSQI [0–3]												
Sleep quality ²	-0.30	(-0.50;-0.11)	0.42	-0.30	(-0.53;-0.07)	0.41	0.07	(-0.15;0.28)	0.09	0.07	(-0.10;0.23)	0.09
Sleep latency ²	-0.35	(-0.61;-0.09)	0.45	-0.28	(-0.51;-0.04)	0.35	0.03	(-0.27;0.34)	0.03	0.03	(-0.22;0.28)	0.03
Sleep duration ²	-0.21	(-0.47;0.06)	0.28	-0.09	(-0.34;0.16)	0.12	0.00	(-0.24;0.24)	0.00	0.00	(-0.24;0.24)	0.00

Notes ¹ high = pos., ² low = pos. HRV-BfB = heart rate variability biofeedback, CI = 95% confidence interval, ES = Cohen's *d* effect size. **Bold** indicates confidence intervals that do not contain zero.

Work-related stress, a common health problem, can affect physical and mental well-being, promote burnout or other stress-related illnesses (Rabe et al., 2012), and contribute to several risk factors for declining health (e.g., disturbed sleep) (Mistretta et al., 2018). Improving employees' resilience, i.e., the ability to maintain physical and mental homeostasis or quickly rebalance when exposed to stressful stimuli, appears to be crucial in addressing increasing workplace stress (An et al., 2020). Resilience is dynamic, and individuals can generate adaptive responses to stress or major difficulties and actively recover from them (Dong et al., 2018; Mistretta et al., 2018; Weber et al., 2019). ANS flexibility is important for adaptive stress response and might be a cause for individual differences in resilience levels (An et al., 2020). HRV-BfB is likely to increase employee resilience because it increases vagal activity and stimulates the parasympathetic reflexes RSA and BR (Lehrer et al., 2020; Lehrer & Gevirtz, 2014). In the present study, HRV-BfB resilience training at work improved not only burnout and stress symptoms, but also self-reported sleep quality, general health, and HRV parameter SDNN (increase), which may result from higher PNS activity and stronger parasympathetic reflexes. In a meta-analysis of 24 studies, Goessl, Curtiss and Hofmann reported large reductions in self-reported stress and anxiety after HRV-BfB interventions, although with heterogeneous effect sizes (Goessl et al., 2017). Similar findings were reported by Lehrer and colleagues who performed a systematic review and meta-analysis of HRV-BfB that included 58 studies addressing various biological and psychological functions and symptoms. The authors found the largest effect sizes for HRV-BfB for depression, anxiety, anger and athletic/artistic performance, while the effect sizes for sleep and quality of life were small (Lehrer et al., 2020). Weber, Lorenz and Hemmings showed that a four-week smartphone-based health intervention improved employees' perceived stress, sleep problems, well-being, and resilience, with effects persisting at six-week follow-up (Weber et al., 2019). Sutarto, Wahab and Zin examined the effects of a five-week BfB training based on resonance frequency breathing in manufacturing operators and found significant improvements of stress, anxiety, depression and an increase in the low frequency HRV (0.05–0.15 Hz, associated with BR gain) (Sutarto et al., 2012). Brinkmann and colleagues compared the effects of a six-week HRV-BfB training and mindfulness-based intervention in employees with waitlist controls and detected within-improvements for perceived stress, coping and SDNN with small to medium effect sizes in all groups (Brinkmann et al., 2020). Although the application of HRV-BfB training seems to be promising for reducing stress symptoms in employees, we found no significant differences between the HRV-BfB and the waitlist control condition with the exception of the sleep parameters. This is

Fig. 3 Cohen's *d* effect sizes for the changes in Copenhagen Psychosocial Questionnaire (COPSOQ) and Pittsburgh Sleep Quality Index (PSQI) as a function of time (HRV-BfB = heart rate variability biofeedback, T0 = pre-intervention, T1 = post-intervention, T2 = follow-up)



in accordance with the results of Brinkmann and colleagues, which could point to a potential influence of other, non-specific intervention factors (e.g., employees feel acknowledged in their needs for support or group experience) on the study results (Brinkmann et al., 2020). In the present study, the digital instruction format achieved higher effect sizes for within-improvements in burnout symptoms and sleep quality and integration into private and professional life tended to be better. This is supported by the results of other studies, which show that digital training is at least as effective as live interventions (Hsieh et al., 2020; Solomon et al., 2004). Thus, digital-only intervention may be superior to blended or face-to-face learning as it is easier to implement (no time or place restrictions) (Hsieh et al., 2020) and employees can exercise at their own pace (Weber et al., 2019). Moreover, due to the COVID-19 pandemic with social distancing and contact restrictions, digital-only approaches are becoming increasingly important. Despite higher effect sizes for digital, however, about 20% of this group would retrospectively prefer live training for social reasons (personal attention and interaction with others). This is in line with the significant rating difference relating to support, with better ratings for the live format. Effects could be intensified by the jointly experienced workplace intervention, where in

a social context employees motivate and encourage each other (Brinkmann et al., 2020; Smit et al., 2023; Weber et al., 2019). However, the costs for resilience training with mobile HRV-BfB and live instruction (300 € per employee) were slightly higher than for the digital-only approach (240 € per employee). Nonetheless, a systematic review found that workplace health promotion interventions had a positive return on investment of 138% (Street & Lacey, 2019) through improved productivity (lowered absenteeism and presenteeism) and reduced healthcare costs (Street & Lacey, 2019; Sutarto et al., 2012).

A major limitation of the present study is the lack of randomization. The study had to be conducted in agreement with the management and the company medical officer of the participating company. They supported the project, but the study was to be carried out with the least possible disruption to daily work processes. Therefore, we decided to assign field staff to HRV-BfB digital because this instructional format was most compatible with the varying daily schedules of these participants. Attending the in-person instruction sessions at the company would have involved more organizational effort and possible disruption to these employees' work routines. However, non-randomization resulted in an inhomogeneous age distribution in the study

Table 5 Mean values and *between*-analysis for study outcome measures in dependence of the biofeedback instruction format at pre-intervention (T0), post-intervention (T1), and follow-up (T2)

	live instruction (<i>n</i> = 24)			digital instruction (<i>n</i> = 19)			live vs. digital: Diff (CI); ES		
	T0	T1	T2	T0	T1	T2	T0	T1	T2
COPSOQ [0–100]									
Personal burnout ²	52.60 ± 12.15	46.01 ± 17.78	45.49 ± 15.68	50.66 ± 13.34	35.97 ± 19.90	37.05 ± 16.01	1.95 (-6.04;9.93); 0.15	10.04(-1.78;21.86); 0.54	8.44(-1.42;18.30); 0.53
General health ¹	66.25 ± 16.89	70.42 ± 17.06	70.83 ± 18.86	74.21 ± 13.87	79.47 ± 9.11	75.11 ± 16.76	-7.96 (-17.44;1.52); 0.51	-9.06 (-17.29;-0.82); 0.64	-4.27(-15.26;6.72); 0.24
Behavioral stress symptoms ²	40.23 ± 17.20	28.51 ± 14.61	29.56 ± 15.11	34.70 ± 17.67	24.84 ± 18.06	23.79 ± 15.88	5.53 (-5.32;16.39); 0.32	3.68(-6.69;14.05); 0.23	5.77(-3.90;15.44); 0.37
Cognitive stress symptoms ²	44.79 ± 16.03	34.11 ± 16.69	35.42 ± 19.21	38.49 ± 19.01	25.33 ± 19.93	26.34 ± 19.04	6.30 (-4.76;17.37); 0.36	8.79(-2.79;20.36); 0.48	9.08(-2.80;20.95); 0.47
Work-privacy conflict ²	45.83 ± 24.77	40.62 ± 23.67	37.50 ± 27.40	48.68 ± 27.21	40.46 ± 27.67	34.03 ± 25.19	-2.85 (-19.13;13.43); 0.11	0.16(-16.02;16.35); 0.01	3.47(-12.78;19.72); 0.13
PSQI [0–3]									
Sleep quality ²	1.25 ± 0.79	1.04 ± 0.69	1.08 ± 0.72	1.42 ± 0.69	1.00 ± 0.75	0.95 ± 0.78	-0.17 (-0.63;0.29); 0.23	0.04(-0.41;0.49); 0.06	0.14(-0.33;0.60); 0.18
Sleep latency ²	1.08 ± 0.97	0.79 ± 0.72	0.71 ± 0.75	0.84 ± 0.76	0.42 ± 0.51	0.68 ± 0.58	0.24 (-0.29;0.78); 0.27	0.37(-0.01;0.75); 0.58	0.02(-0.39;0.43); 0.04
Sleep duration ²	0.88 ± 0.80	0.67 ± 0.70	0.71 ± 0.75	0.79 ± 0.79	0.58 ± 0.69	0.79 ± 0.79	0.09 (-0.41;0.58); 0.11	0.09(-0.35;0.52); 0.13	-0.08(-0.56;0.40); 0.11
HRV									
Heart rate [1/min] ²	72.86 ± 10.01	73.89 ± 8.33	-	71.42 ± 9.33	74.53 ± 10.61	-	1.44(-1.94;4.82); 0.15	-0.64(-4.04;2.76); 0.07	-
pNN50 [%] ¹	16.79 ± 13.28	16.90 ± 12.54	-	19.65 ± 16.00	20.03 ± 14.14	-	-2.87(-8.09;2.36); 0.20	-3.13(-7.86;1.59); 0.24	-
RMSSD [ms] ¹	40.00 ± 17.69	41.51 ± 17.97	-	44.67 ± 23.78	45.49 ± 22.34	-	-4.67(-12.17;2.82); 0.23	-3.98(-11.19;3.23); 0.20	-
SDNN [ms] ¹	62.33 ± 26.44	68.77 ± 24.81	-	69.30 ± 31.97	76.11 ± 33.62	-	-6.97(-17.39;3.45); 0.24	-7.35(-17.91;3.22); 0.25	-
Stress index [pts] ²	126.33 ± 85.27	110.36 ± 77.46	-	136.28 ± 110.37	140.36 ± 161.66	-	-9.95(-45.13;25.23); 0.10	-30.00(-76.36;16.36); 0.25	-

Notes Data are means ± SD. ¹ high = pos., ² low = pos. COPSOQ = Copenhagen Psychosocial Questionnaire, PSQI = Pittsburgh Sleep Quality Index, HRV = heart rate variability, Diff = mean difference, CI = 95% confidence interval, ES = Cohen's *d* effect size. **Bold** indicates confidence intervals that do not contain zero

Table 6 *Within-analysis for study outcome measures in dependence of the biofeedback instruction format, post-intervention (T1) and follow-up (T2) versus pre-intervention (T0)*

	live learning (<i>n</i> = 24)						digital learning (<i>n</i> = 19)					
	T1 vs. T0			T2 vs. T0			T1 vs. T0			T2 vs. T0		
	Diff	CI	ES	Diff	CI	ES	Diff	CI	ES	Diff	CI	ES
COPSOQ [0–100]												
Personal burnout ²	-6.60	(-11.60;-1.60)	0.43	-7.12	(-10.87;-3.36)	0.51	-14.69	(-22.22;-7.17)	0.87	-13.61	(-19.85;-7.37)	0.92
General health ¹	4.17	(-1.66;10.00)	0.25	4.58	(-1.12;10.29)	0.26	5.26	(0.62;9.91)	0.45	0.89	(-5.26;7.05)	0.06
Behavioral stress symptoms ²	-11.72	(-18.63;-4.81)	0.73	-10.68	(-17.67;-3.69)	0.66	-9.87	(-18.48;-1.25)	0.55	-10.92	(-17.69;-4.15)	0.65
Cognitive stress symptoms ²	-10.68	(-15.63;-5.73)	0.65	-9.38	(-16.11;-2.64)	0.53	-13.16	(-22.63;-3.69)	0.68	-12.15	(-20.56;-3.73)	0.64
Work-privacy conflict ²	-5.21	(-11.17;0.75)	0.21	-8.33	(-14.92;-1.75)	0.32	-8.22	(-17.91;1.46)	0.30	-14.65	(-23.17;-6.14)	0.56
PSQI [0–3]												
Sleep quality ²	-0.21	(-0.46;0.04)	0.28	-0.17	(-0.46;0.13)	0.22	-0.42	(-0.75;-0.09)	0.59	-0.47	(-0.85;-0.10)	0.64
Sleep latency ²	-0.29	(-0.68;0.09)	0.34	-0.38	(-0.72;-0.03)	0.43	-0.42	(-0.79;-0.05)	0.65	-0.16	(-0.49;0.17)	0.23
Sleep duration ²	-0.21	(-0.60;0.19)	0.28	-0.17	(-0.53;0.20)	0.22	-0.21	(-0.59;0.17)	0.28	0.00	(-0.36;0.36)	0.00
HRV												
Heart rate [1/min] ²	1.03	(-1.06;3.12)	0.11	-	-	-	3.11	(0.07;6.14)	0.31	-	-	-
pNN50 [%] ¹	0.11	(-3.10;3.33)	0.01	-	-	-	0.38	(-3.78;4.54)	0.03	-	-	-
RMSSD [ms] ¹	1.51	(-3.01;6.03)	0.08	-	-	-	0.82	(-6.08;7.72)	0.04	-	-	-
SDNN [ms] ¹	6.44	(-1.09;13.98)	0.25	-	-	-	6.82	(-1.70;15.33)	0.21	-	-	-
Stress index [pts] ²	-15.97	(-38.38;6.44)	0.20	-	-	-	4.08	(-32.51;40.67)	0.03	-	-	-

Notes ¹ high = pos., ² low = pos. HRV-BfB = heart rate variability biofeedback, CI = 95% confidence interval, ES = Cohen's *d* effect size. **Bold** indicates confidence intervals that do not contain zero.

Fig. 4 Cohen's d effect sizes for the changes in Copenhagen Psychosocial Questionnaire (COPSOQ) and Pittsburgh Sleep Quality Index (PSQI) as a function of time (T0 = pre-intervention, T1 = post-intervention, T2 = follow-up) – ancillary analysis

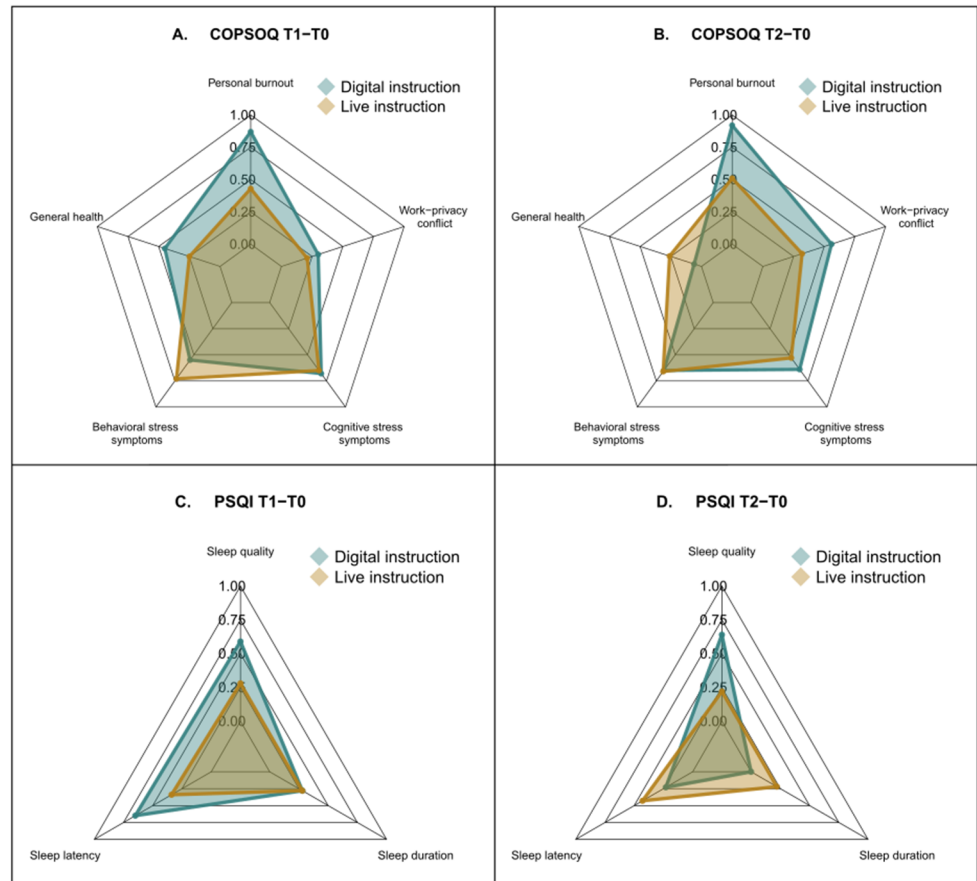


Fig. 5 Mean changes in sleep quality, as measured by the Pittsburgh Sleep Quality Index (PSQI), across time points for both groups (HRV-BfB = heart rate variability biofeedback). Time points include T0 (pre-intervention), T1 (post-intervention), and T2 (follow-up). Lower values indicate better sleep quality

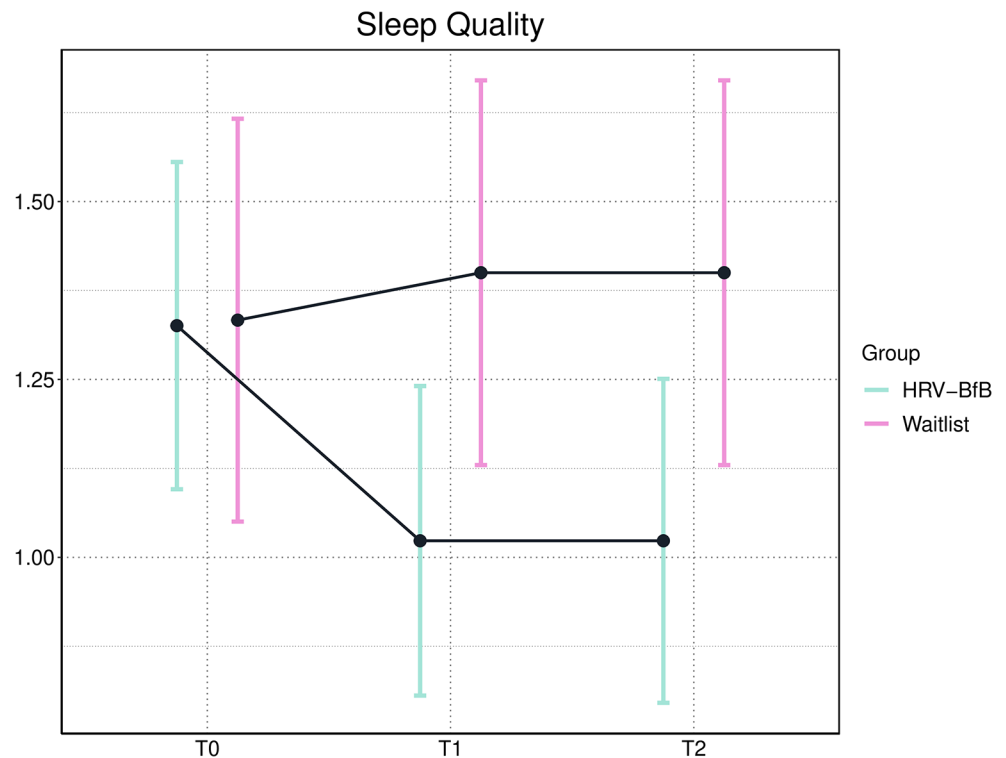


Table 7 Within-analysis of HRV parameters from pre- (T0) to post-intervention (T1) in the bio-feedback condition (HRV-BfB) ($n = 43$)

			T0 vs. T1		
	T0	T1	Diff	CI	ES
Heart rate [1/min] ²	72.23 ± 9.70	74.17 ± 9.37	1.95	(0.19;3.71)	0.20
pNN50 [%] ¹	18.05 ± 14.55	18.28 ± 13.31	0.23	(-2.30;2.76)	0.02
RMSSD [ms] ¹	42.06 ± 20.65	43.27 ± 20.03	1.21	(-2.70;5.11)	0.06
SDNN [ms] ¹	65.41 ± 29.11	72.01 ± 29.14	6.61	(1.04;12.17)	0.23
Stress index [pts] ²	130.73 ± 96.88	123.62 ± 122.41	-7.11	(-27.32;13.11)	0.06

Notes Data are means ± SD. ¹ high = pos., ² low = pos. Diff = mean difference, CI = 95% confidence interval, ES = Cohen's *d* effect size. **Bold** indicates confidence intervals that do not contain zero.

Table 8 Evaluation of the HRV-BfB training at post-intervention (T1)

	HRV-BfB ($n = 43$)	live learning ($n = 24$)	digital learning ($n = 19$)	live vs. digital: Diff (CI); ES
Training success	2.07 ± 0.59	2.04 ± 0.55	2.11 ± 0.66	-0.06 [-0.45; 0.32]; 0.11
Integration into professional life	2.98 ± 1.26	3.21 ± 1.10	2.68 ± 1.42	0.52 [-0.28;1.33]; 0.42
Integration into private life	2.14 ± 0.86	2.33 ± 0.87	1.89 ± 0.81	0.44 [-0.08;0.96]; 0.52
Support	1.70 ± 0.89	1.29 ± 0.55	2.21 ± 0.98	-0.92 (-0.43;-0.40); 1.20

Notes Data are means ± SD. Scale from 1 = positive to 5 = negative. HRV-BfB = heart rate variability bio-feedback, Diff = mean difference, CI = 95% confidence interval, ES = Cohen's *d* effect size. **Bold** indicates confidence intervals that do not contain zero

groups, with a higher share of younger employees attending HRV-BfB. In order to obtain valid data, a training period of at least two weeks was specified for the data to be included in the analysis. This resulted in the data of 17 participants being excluded from the analysis due to poor training adherence (less than two weeks). However, compared to the active group, these 17 participants had significantly higher baseline values for burnout and stress parameters (they were more stressed) and reported poorer sleep quality. Thus, the exclusion of these data sets may have biased our results. Moreover, the fact that the excluded participants reported a higher stress burden could indicate that those most in need of help have difficulty persevering with the intervention, at least when it is designed as in our study and relies strongly on people's own initiative to carry out the training. Brinkmann and colleagues report that the benefit of HRV-BfB on HRV was strongest under stress exposure, not at rest (Brinkmann et al., 2020). Thus, it remains an open question whether measuring HRV parameters during stress exposure would have provided more clear-cut results. Furthermore, because we did not measure HRV in the waitlist control condition, we cannot say with certainty that the observed improvements were due to HRV-BfB alone.

Conclusion

Four-week resilience training with mobile HRV-BfB reduced stress in employees and could contribute to preventive health-care. No significant differences were seen between digital and live instructional format with respect to training success

or behavior change. Digital instruction is easier to implement and yielded slightly higher effect sizes, whereas live learning achieved higher training motivation (better training adherence) and better ratings for social aspects. Both formats increased employee resilience and companies should choose the approach that best fits the company profile (e.g., digital formats for young and dynamic companies or start-ups) or ideally offer both formats to meet the different preferences of employees. Future studies should implement randomized designs with larger sample sizes. HRV measurements under stress exposure should be performed in all groups.

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Author Contributions JV contributed to the conception and design of the study, the acquisition, analysis and interpretation of the data and the drafting and revision of the manuscript. HS contributed to the conception and design of the study, the interpretation of the data and the revision of the manuscript. MI contributed to the analysis and interpretation of the data and the revision of the manuscript. MS contributed to the interpretation of the data and the drafting and revision of the manuscript. SK contributed to the analysis and interpretation of the data and the drafting and revision of the manuscript. IK contributed to the interpretation of the data and critically revised the manuscript for important intellectual content. KV contributed to the conception and design of the study, the interpretation of the data and the drafting and revision of the manuscript. All authors read and approved the final manuscript.

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was at no time involved in the study, data analysis or manuscript preparation.

Data Availability The data used to support the findings of this study are available on reasonable request from the corresponding author.

Declarations

Ethics Approval The study was approved by the Ethics Committee of the Medical Association of Baden-Württemberg in Stuttgart, Germany (approval number: F-2016-091).

Consent to Participate Written informed consent was obtained from all participants prior to their inclusion in the study.

Competing Interests Inna Khazan is one of the authors of the present work and is also a member of the Applied Psychophysiology and Biofeedback's Editorial Board.

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