Does Mindfulness Improve After Heart Coherence Training in Patients With Chronic Musculoskeletal Pain and Healthy Subjects?

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ORIGINAL ARTICLE

Does Mindfulness Improve After Heart Coherence Training in Patients With Chronic Musculoskeletal Pain and Healthy Subjects? A Pilot Study

慢性肌肉骨骼疼痛患者和健康受试者在接受心脏协调性训练之后正念度是否有改善？一项初步研究

¿Mejora la concienciación después del entrenamiento de coherencia cardíaca en pacientes con dolor musculoesquelético crónico y en sujetos sanos? Estudio piloto

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Mindfulness, heart rate variability, heart coherence training, acceptance and commitment therapy, chronic pain

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ABSTRACT

Background: Mindfulness and heart coherence training (HCT) training are applied increasingly in the treatment of patients with chronic musculoskeletal pain (CMP). Questionnaires have been developed to assess changes in mindfulness but no gold standard is available.

Objective: Explore the relationship between changes in mindfulness scores and changes in heart coherence after 3 sessions of HCT in patients with CMP and in healthy subjects.

Research Method/Design: Ten patients with CMP and 15 healthy subjects were trained in self-regulation with the use of HCT following a standardized stress relief program developed by the HeartMath Institute. A heart coherence-score (HC-score) was constructed with scores ranging from 0-100 with higher scores reflecting more heart rate variability (HRV) coherency. Change scores, Spearman correlation coefficients, and Wilcoxon Signed Rank test were calculated to test relationships and differences between HC-score, the Mindfulness Attention and Awareness Scale (MAAS) and Five Facet Mindfulness Questionnaire (FFMQ). A new questionnaire was constructed to explore on which mindfulness-related domains patients with CMP report changes after HCT.

Results: Increases were present on HC-score in healthy subjects ($P<.01$) and in patients ($P<.01$) between baseline and follow-up. Effect sizes on change on the MAAS and FFMQ were low. Weak ($r<0.25$) and non-significant correlations were observed in change scores between HC-score and MAAS or FFMQ. Patients reported significant favorable differences on 6 mindfulness related domains in the new questionnaire: breathing rhythm, physical awareness, positive or negative emotions, recognition of stressful situations, thoughts, and tendency to actively self-regulate.

Conclusions: In this pilot study, mindfulness as assessed by the MAAS and FFMQ does not appear to improve after HCT. HRV coherency, MAAS, and FFMQ measure different constructs and are weakly related. It is of great importance to choose and develop valid measures that reflect patients' states of mindfulness. Content and face validity of measures of mindfulness may be considered in the light of performance-based measures.

摘要

背景：正念度和心脏协调性训练（HCT） 越来越多地应用于慢性肌肉骨骼疼痛（CMP）患者的治疗。目前已有评估正念度变化的调查问卷，但尚无金标准。

目的：探讨 CMP 患者和健康受试者在接受 3 次 HCT 训练后的正念度得分变化与心脏协调性变化之间的关系。

研究方法/设计：10 名 CMP 患者和 15 名健康受试者在完成由 HeartMath Institute 开发的标准化减压课程之后，接受了 HCT 自我调节培训。心脏协调性得分（HC 得分）的分值位于 0-100 范围内，分值越高，说明心率变化（HRV）的协调性越好。通过计算分值变化、Spearman 相关系数和 Wilcoxon 符号秩检验，我们评估了 HC 分值、正念注意觉知量表（MAAS）得分和五因素正念度调查问卷（FFMQ）得分之间的关系及差异。我们编制了一则新的调查问卷，以探查 CMP 患者在接受 HCT 后会在哪些正念相关域出现变化。

结果：健康受试者（$P<0.01$）和患者（$P<0.01$）的 HC 得分从基线期到随访期出现了升高。MAAS 和 FFMQ 得分的改善程度较低。HC 得分变化与 MAAS 或 FFMQ 得分变化之间存在微弱（$r<0.25$）和非显著的关联。患者在新编调查问卷的以下 6 个正念相关域上表现出了显著、有利的差异：呼吸节律、身体觉知、良性或负性情绪、应激情形识别、认知以及主动自我调节能力。

结论：这项初步研究表明，由 MAAS 和 FFMQ 评定的正念度得分在 HCT 之后似乎未见改善。HRV 协调性、MAAS 和 FFMQ 测量的是不同指标体系，且相互之间关联微弱。选择和编制能够反应患者正念度的高效度评估体系十分重要。正念度评估指标的内容和表面效度可参照基于功能表现的指标进行考虑。

SINOPSIS

Antecedentes: La concienciación y el entrenamiento de coherencia cardíaca (HCT) se aplican cada vez más en el tratamiento de pacientes

con dolor musculoesquelético crónico (DMC). Se han desarrollado cuestionarios para evaluar los cambios en la concienciación, pero no hay un método de referencia disponible.

Objetivo: Explorar la relación entre los cambios en las puntuaciones de concienciación y los cambios en la coherencia cardíaca después de 3 sesiones de HCT en pacientes con DMC y en sujetos sanos.

Método de investigación/Diseño: Diez pacientes con DMC y 15 sujetos sanos recibieron formación en autorregulación con el uso de HCT después de un programa estandarizado de alivio del estrés desarrollado por el Instituto HeartMath. Se elaboró una puntuación de coherencia cardíaca (puntuación HC) con puntuaciones de 0 a 100 en las que las puntuaciones más altas reflejaban mayor coherencia de variabilidad del ritmo cardíaco (HRV). Se calcularon los cambios en las puntuaciones, los coeficientes de correlación de Spearman y la prueba de rangos con signos de Wilcoxon para probar las relaciones y diferencias entre la puntuación HC, la escala Mindfulness Attention and Awareness (MAAS) y el cuestionario Five Facet Mindfulness Questionnaire (FFMQ). Se creó un nuevo cuestionario para explorar en qué dominios relacionados con la concienciación informan los pacientes con DMC de cambios después de la HCT.

Resultados: Los aumentos estuvieron presentes en las puntuaciones de HC en sujetos sanos ($P < 0,01$) y en los pacientes ($P < 0,01$) entre el inicio y seguimiento. Los tamaños del efecto en el cambio en la MAAS y FFMQ eran bajos. Se observaron correlaciones débiles ($r < 0,25$) y no significativas en las puntuaciones de los cambios entre la puntuación HC y MAAS o FFMQ. Los pacientes informaron de diferencias significativas favorables en 6 dominios relacionados con la concienciación en el nuevo cuestionario: el ritmo respiratorio, la conciencia física, las emociones positivas o negativas, el reconocimiento de situaciones estresantes, las cogniciones y la tendencia a la autorregulación activa.

Conclusiones: En este estudio piloto, la concienciación evaluada por la MAAS y el FFMQ no parece mejorar después de la HCT. La coherencia HRV, la MAAS y el FFMQ miden constructos diferentes y están escasamente relacionados. Es de gran importancia elegir y desarrollar medidas válidas que reflejen los estados de concienciación de los pacientes. El contenido y la validez de las medidas de la concienciación podrían ser consideradas a la luz de las medidas basadas en el rendimiento.

INTRODUCTION

Chronic musculoskeletal pain (CMP) is one of the largest contributors to work absenteeism and disability in Western society.[1] Although multidisciplinary behavioural interventions are effective for restoring function, the strength of these treatment effects is modest.[2] To optimize treatment effects, it is of great importance to improve the content and practice of interventions. Where cognitive behavioral therapy (CBT) has dominated in the previous decades, contextual therapies such as acceptance and commitment therapy (ACT), mindfulness or heart Coherence training (HCT)[3] are receiving increasing attention in international literature and some have been found effective in the treatment of chronic pain.[4,5] All of these approaches have a strong experiential character, in which patients learn to become more aware of feelings, thoughts, and physical sensations while learning how to interpret them.

Various meditation trainings can be distinguished, but in general, they are similar in goals.[6] One relatively new method that has been related to mindfulness therapy has previously been suggested with the use of HCT.[7,8] However, the theoretical concepts underlying mindfulness differ from those of HCT. Mindfulness focuses on awareness and acceptance, while in HCT, the objective is to be aware and act effectively on what is occurring through self-regulation processes that are associated with changes in afferent cardiovascular inputs to the brain. HCT is facilitated with the use of biofeedback systems in which real-time feedback of heart coherence can be displayed on a screen.[9] HCT is based on a person's heart rate variability (HRV) patterns, which are sensitive to changes in state that are evoked by stress, emotions, breathing rhythm and attention. The stability of the coherent pattern in HRV is formed by factors including sympathetic and parasympathetic activity, emotional state, breathing rhythm or physical activity.[10] The training has an experiential character and focuses on physical, emotional and cognitive experiences, which may be related to mindfulness domains. In a previous pilot study, a relationship between effect in HCT and mindfulness assessed by the Mindfulness Attention and Awareness Scale (MAAS) was reported in a group of patients suffering from anxiety and mood disorders.[7] It is however insufficiently clear if changes in heart coherence after HCT are related to changes in mindfulness scores as reported on the MAAS or other mindfulness instruments such as the Five Facet Mindfulness Questionnaire (FFMQ).

To gain more knowledge on possible relations between mindfulness and heart coherence, we conducted a pilot study to explore:

1. the relationship between changes in mindfulness and HRV Coherence after 3 sessions of HCT in patients with CMP and in healthy subjects;
2. possible changes in factors related to mindfulness after HCT; and
3. whether mindfulness and heart coherence scores are directly correlated and whether mindfulness scores will increase after HCT.

METHODS

Design

In this study, patients with CMP and healthy subjects without CMP participated. This study followed a prospective pre-post treatment design. A pilot study

was conducted because no other studies are known to describe the relationship between HC-scores and self-reported mindfulness in patients with CMP. Both groups received three 1-hour sessions of HCT.

Participants

In total, 10 patients and 15 healthy subjects were included in this study. Patients were recruited from a multidisciplinary rehabilitation program of the Center for Rehabilitation at the University Medical Center Groningen in The Netherlands. Included were patients with CMP (>3 months) between 18 and 65 years of age. CMP diagnoses were made by a rehabilitation physician. Excluded were patients with an underlying specific medical cause, comorbidity with severe negative consequences for physical and/or mental functioning, addiction to drugs, and insufficient knowledge of the Dutch language. HCT supplemented usual care. Six therapy sessions were provided, but data were analyzed after 3 HCT sessions. Healthy subjects were recruited from advertisements, and most were university students. Healthy subjects received €30 ($33.45 US) for completing 3 training sessions. Institutional review board approval was not obtained because the patient data used for this study were collected as part of care as usual and derived from the medical records. All Dutch patients signed informed consent stating that the data can anonymously be used by their treating physicians for analyses of the outcomes of care. The handling of the data was done in accordance with the guidelines for good research practice.

Procedures

At baseline (T_0), patients filled out a set of questionnaires, including the Dutch MAAS[11] and the Dutch FFMQ.[12] Use of two mindfulness questionnaires was chosen because no gold standard is available and concurrent validity of mindfulness questionnaires has previously been found to be moderate.[13] The MAAS was chosen for its good psychometric properties and because a trait-like situation is measured.[14] The FFMQ was chosen because it aims to measure 5 facets of mindfulness, including state-like properties. Additionally, the Pain Disability Index (PDI)[15] and the Roland Morris Disability Questionnaire (RMDQ)[16] were administered at baseline to describe the patient group. Healthy subjects were not disabled and did not fill out the PDI and RMDQ. After the third training (T1), both groups completed the MAAS and the FFMQ. HC-score was measured at To and T1 and reflected their resting heart coherence in which patients were not instructed to use any meditation technique.

Intervention

HCT was provided by licensed physiotherapists with the EmWave Computer biofeedback system of the HeartMath Institute (Boulder Creek, California).[17] Both groups received 3 training sessions of 1 hour in self-regulation and were instructed to practice at home on a daily basis. Sessions were provided at 1-week intervals. During the training, subjects were taught 3 self-regulation techniques: neutral, quick coherence, and the heart lock-in. The neutral technique is proposed as a mindfulness-related technique and forms the first step of the other techniques. It entails being attentive to the heart area and mentally imaging breathing in and out throughout the heart area. In the quick coherence technique, participants are encouraged to feel a positive emotion. In the heart lock-in technique, a long-lasting attentive exercise (10 minutes) is provided to teach subjects to sustain focus and place attention on the body and environment while maintaining a positive emotion such as appreciation, care, or compassion.

MEASUREMENTS

Mindfulness Questionnaires

The Dutch Language Version MAAS consists of 15 items that are scored on a 6-point Likert scale, ranging from 1 (almost always) to 6 (almost never). Scores of all questions are summed. Score range is 15 to 90 with higher scores reflecting more mindfulness. The MAAS measures 1 dimension, and reliability and construct validity were deemed sufficient.[12] Validity of the Dutch version was deemed appropriate for training and therapy settings.[11]

The Dutch Language FFMQ is a validated scale that aims to assess 5 facets of a general tendency to be mindful in daily life: observing, describing, acting with awareness, nonreactivity and nonjudging of inner experience.[9] The questionnaire consists of 39 items, which are scored on a 5-point Likert scale ranging from 1 (never or very rarely true) to 5 (very often or always true). Score range is 39 to 195 with higher scores indicating more mindfulness.[12]

An evaluation form was constructed by the authors to explore mindfulness-related changes that include constructs we felt were missing from the other assessments. This questionnaire contained 6 questions based on the most frequently mentioned differences of mindfulness-related domains which were gathered from approximately 150 patients with CMP who received HCT 2 years prior to this study. The 6 questions reflect changes in breathing rhythm, physical awareness, positive or negative emotions, recognition of stressful situations, thoughts, and tendency to actively self-regulate. Subjects were asked to rate their changes on a 4-point Likert scale ranging from 0 (no difference) to 3 (great difference). The questionnaire is presented in the Box. Although the psychometric properties of this questionnaire are presently unknown, it appears to have good face validity.

Heart Coherence Score

HRV was measured with an ear sensor that gave real-time feedback with the use of the EmWave Pro, a hardware/software system that teaches techniques to help create an optimal state of coherency. Based on the

Box Evaluation Form: Mindfulness and Heart Coherence Training

In which domains did Heart Coherence Training contribute to a change in your pain problem? (Translated from Dutch) All questions could be answered with "none," "little," "moderate," or "large."

a. Your breathing rhythm
b. Your physical sensations
c. Coping with emotions
d. Recognition of sensations
e. Your coping with thoughts
f. Your tendency to act these articles.[30]

HRV, EmWave calculates and displays visually a coherence score. A coherent heart rhythm is defined as a relatively harmonic, sine wave–like, signal with a very narrow, high-amplitude peak, often in the low-frequency region of the HRV power spectrum with no major peaks in the very low–frequency or upper portion of the high-frequency regions. Coherence is assessed by identifying the maximum peak in the 0.04 Hz-0.26 Hz range of the HRV power spectrum, calculating the integral in a window 0.030 Hz wide, centered on the highest peak in that region, and then calculating the total power of the entire spectrum. The coherence ratio is formulated as: (Peak Power/[Total Power – Peak Power]). The coherence score is updated every 5 seconds.[18] Coherence scores were presented by the EmWave desktop as a percentage of time in either high, medium or low coherence. A green box indicates the percentage of time when subjects are in a high coherence state, a blue box indicates the percentage time that patients are in a medium coherence state, and a red box indicates percentage of time of incoherency. Calculated, these boxes represent 100% of the time. An effect measure was created by calculating the blue and green boxes (red x 0, blue x 1/2; green x 1). This resulted in an average weighted coherence score (HC-score), ranging from 0 to 100 with larger numbers reflecting higher coherency.[7] Stressful feelings, mindlessness, negative emotions and insufficient coping are suggested to be associated with an incoherent HRV pattern. Feelings of appreciation and focusing on body signals such as breathing and the heart area are suggested to be associated with coherency.[19] HC-scores were acquired during a 5-minute measurement during resting conditions. In this case the threshold for a low/medium coherence score was 0.6 and 2.1 for a medium/high coherence score.

Analyses

HCT data on To and T1 were assessed for normality and determined to be non-normal by checking means, medians, modes, skewness, kurtosis, and q-q plots. To test if mindfulness changes after 3 sessions of training, Pearson or Spearman correlation coefficients, and between-subjects analyses were performed using unpaired *t*-tests or Mann Whitney U-tests. To test differences between To and T1, Mann Whitney U-tests and effect sizes (ES) were calculated. ES was defined as a Cohen's d and was scored as the difference between To and T1 scores divided by the standard deviation of To. ES< 0.2 was considered nonsignificant; ES 0.21-0.50 small; ES 0.51-0.80 medium; and ES>0.8 large.[20]

RESULTS

Participants

Ten patients (2 men, 8 women) and 15 healthy subjects (4 men, 11 women) participated in this study. Mean age (years) of patients was 50 ± 9 and 22 ± 5 for healthy subjects. Mean disability of patients reported on the PDI at To was 30.0 ± 14.6 and 21.6 ± 17.1 at T1. Mean RMDQ score of patients at To was 13.1 ± 4.5 and 7.7 ± 4.6 at T1. HCT data on To and T1 did not meet criteria for normality mainly because of the small groups of included subjects; therefore, nonparametric tests were used. Resting baseline data of HC-scores were not significantly different between healthy subjects and patients.

Outcome

Correlations coefficients between change scores HCT and MAAS were –0.13 for patients (P=.70) and –0.00 for healthy subjects (P=.99). Correlations between changes in HC-score and subscales of the FFMQ are overall weak to fair but nonsignificant (Table 1).

Significant differences were present between To and T1 on the MAAS in healthy subjects but not in patients. In both patients and healthy subjects, differences in HC-score between To and T1 were observed with large effect sizes (2.1 and 2.7 respectively; P<0.01). Other differences were small and nonsignificant (Table 2). The baseline HC-score of patients was nonsignificantly lower than of healthy subjects. On the evaluation form, patients reported large changes in the 6 mindfulness-related domains (Table 3).

DISCUSSION

The main objective of this study was to explore if HCT is related to self-reported measures of mindful-

Table 1 Pearson Correlations Between Changes in Mindfulness Questionnaires (MAAS and FFMQ) and Changes in HC-score

	ΔMAAS	ΔFFMQ	ΔObserving[a]	ΔDescribe[a]	ΔAct[a]	ΔNonreact[a]	ΔNonjudge[a]
ΔHCT Patients	–0.13	0.20	–0.17	0.36	0.07	0.37	0.09
ΔHCT Healthy subjects	0.00	–0.31	–0.13	0.13	–0.38	0.02	–0.34

Δ= difference between T1 and T0. All correlations were non-significant.
[a] subscale of FFMQ.
Abbreviations: FFMQ, Five Facet Mindfulness Questionnaire; HCT, heart coherence training; MAAS, Mindfulness Attention and Awareness Scale.

Table 2 Intervention Effects on HCT and Self-reported Mindfulness of Patients and Healthy Subjects

	T0 Median (IQR)	T1 Median (IQR)	ES	Z	*P* value
Healthy Subjects (N=15)					
HC-score(scale 0-100)	47 (29-111)	178 (100-194)	2.1	–3.1	.00[a]
MAAS score(scale 15-90)	62 (51-65)	58 (51-59)	–0.4	–2.0	.04[a]
FFMQ Score(scale 39-195)	129 (125-141)	134 (130-138)	0.1	–1.2	.23
Patients (N=10)					
HC-Score(scale 0-100)	32(12-53)	165 (83-191)	2.7	–2.8	.00[a]
MAAS score(scale 15-90)	53 (36-59)	55 (51-65)	0.6	–0.95	.34
FFMQ Score(scale 39-195)	135 (132-144)	135 (131-156)	0.4	–1.3	.18

[a] significant at $P<.05$.
Abbreviations: FFMQ, Five Facet Mindfulness Questionnaire; ES, effect size; HC-score, heart coherence score; MAAS, Mindfulness Attention and Awareness Scale; Z, Z-value of Wilcoxon Signed Rank test.

Table 3 Results of Self-reported Changes on the Evaluation Form Concerning 6 Mindfulness-related Domains on 4-point Likert Scale (0=no difference; 3=great difference)

	Mindfulness related question					
	Breathing rhythm	Physical sensations	Coping of emotions	Recognition of sensation	Coping of thoughts	Tendency to act
Median change	2.5	3	3	3	2.5	3
Minimum/Maximum	0-3	1-3	1-3	1-3	2-3	1-3

ness. Mainly nonsignificant and weak correlations were identified between HCT and self-reported mindfulness measured by the FFMQ and the MAAS. After 3 training sessions of HCT, patients and healthy subjects were more responsive to heart coherence change compared to changes in mindfulness. Patients, however, reported large differences in the 6 mindfulness-related domains of the questionnaire that was constructed to assess changes in breathing rhythm, physical awareness, positive or negative emotions, recognition of stressful situations, thoughts, and tendency to actively self-regulate.

It may be disputed whether MAAS or FFMQ best approaches the construct of mindfulness. On face validity, it may be recommended to use a performance-based measure for mindfulness because of the strong experiential character of mindfulness. However, questionnaires such as the MAAS or FFMQ are considered to have good construct validity and reliability and are not intended to measure tendency to act on (potential) stressors. However, concurrent validity of both questionnaires is unknown. In previous research, the MAAS was compared to 4 other mindfulness scales.[13] The authors observed significant but weak to fair correlations between different mindfulness questionnaires (correlations ranging from 0.31 to 0.67). Post hoc comparisons between the correlations of the MAAS and the FFMQ in our study revealed a correlation at T0 of 0.02 ($P=.94$), and at T1 a correlation of $r=0.56$ ($P<.02$). Correlation of change scores (T1-T0) between the MAAS and FFMQ were nonsignificant (r=0.17). Operationalization of the construct of mindfulness therefore remains challenging, and additional research of mindfulness questionnaires and the effectiveness of mindfulness training is necessary. It is recommended to use not only 1 instrument because concurrent validity among all measurements is insufficient and no gold standard is available.

The content of the HCT in this study was based on the standardized techniques used with the HeartMath stress relief program.[17] The main purpose of the HCT was to teach patients to be more attentive to signals within and outside of themselves and to learn to self-regulate feelings and perceptions of stress. For many patients, this led to being attentive to different personal domains. Therefore, the self-constructed questionnaire of 6 mindfulness related questions was used. Substantial changes appeared in these domains after HCT, compared to no or minor changes in the FFMQ and MAAS. A possible explanation may be that after 3 sessions of HCT, patients are just starting to become aware of their emotions, thoughts, or experiences (more state-like). In contrast, 3 sessions of HCT may lead to fewer improvements on mindfulness questionnaires, which are more trait-like. Another possible explanation could also be that patients learned to speak and use the words that were used by the therapist in the training and therefore are more responsive to this questionnaire than to the FFMQ and MAAS questionnaires.

There are several limitations to this study. This was a pilot with a small sample size. No randomization or nonintervention control group was used. The groups significantly differed in age, which is known to be inversely correlated with HRV.[21] Given the small sample size, there was inadequate power to determine

the significance of the correlations.

There may be a range of underlying mechanisms to explain the results of this study. In the first place, it was hypothesized that mindfulness measured by patient-reported outcome measures would moderately correlate with HCT. This appeared differently. Because the changes on HC-score in healthy subjects were similar to patients, HCT may also be related to increase in general health benefits such as lower stress hormones and lower blood pressure.[10,22] Secondly, the nature of the questionnaires may differ from HCT as it reflects the current state of the person; however, there was a trend that patients had lower resting HC-scores, meaning that CMP may decrease HRV over a longer period. Patients were thought to change their heart coherence within seconds or minutes and to act (self-regulate) instead of just being attentive. Although it has previously been stated that the MAAS has been designed as a trait-like quality that will be manifest as a general tendency to be mindful in daily life,[23] other research found higher scores of mindfulness after training. Lastly, heart coherence may be unrelated to mindfulness. In absence of a good theoretical framework and operational definitions, a gold standard cannot be obtained, and the question remains what exactly mindfulness is and how it should be measured. In future research, all these possible confounders should be taken into account. Whether HCT has additional value in training and measuring mindfulness remains unknown. Further research to the additional value of HCT beyond conventional therapy should be studied in a randomized controlled trial with larger samples and influences on pain and disability should be included.

For clinical practice, it is important to take into account that mindfulness and HC-score do not highly correlate and measure different constructs. Training mindfulness may not automatically lead to an increase in self-regulation skills, and training in self-regulation skills may not lead to higher mindfulness scores.

CONCLUSIONS

In this pilot study, HCT, MAAS, and FFMQ constructs are weakly and nonsignificantly related. After 3 sessions of HCT, HC-score increased, but this was not associated with an effect on self-reported measures of mindfulness. However, changes in breathing rhythm, physical awareness, positive or negative emotions, recognition of stressful situations, thoughts, and tendency to actively self-regulate were reported.

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