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Higher HRV and lower anxiety in buddhist concentrative and zen-seated meditation in response to acute stress

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Abstract

This work deals with comparing heart-rate variability (HRV) in the Buddhist concentrative meditation based on the 16th Karmapa, Zen-seated meditation (zazen), and progressive muscle relaxation – before, during, and after the effects of stress. A number of similar studies have shown the positive psychophysiological effect of meditation; however, the efficiency of particular meditational exercises remains unclear. Another question that remains is what role the level of mindfulness plays in individuals. The thirty participants, belonging to meditation and control groups, performed the corresponding exercise for 15 minutes before and after completing a stressful task (a test for distraction stress). The HRV and anxiety levels were recorded continuously; the mindfulness level was recorded with The Applied Mindfulness Process Scale (AMPS). The results showed that meditating individuals achieved a higher HRV and lower anxiety levels throughout all the measurement stages compared to the control group. In some parameters, concentrative meditation recorded higher levels of HRV than Zen meditation, which can attest to its effects. An interesting discovery is the association of the mindfulness score with the ability to efficiently handle the effects of stress, which at its high level was reflected by a smaller reduction of HRV parameters. The results were interpreted in accordance with the Neurovisceral Integrative Model, which combines the regulation of cardiac activity with activation of brain regions associated with appropriate self-regulatory strategies.

Introduction

To achieve an overall general mental and physical health represents an important issue for the population, thus it is essential to examine the effects of stress on human body as well as stress reduction and prevention techniques. A major physiological stress indicator revealing the significant body functions associated with the ability of adaptability and health (Thayer, Ahs, Fredrikson, Sollers, Wager, 2012), is the heart rate variability (HRV) which is described as the interval between the individual heart beats, and it is often used as the biomarker of the activity of sympathetic and parasympathetic nervous system (Stauss, 2003). In a meta-analysis of 12 studies, Castaldo, Melillo, Bracale, Caserta, Triassi a Pecchia (2015) systematically evaluated the association of acute mental stress and short-term heart rate variability in healthy individuals. They point to the fact that the chronological and non-linear domain associated with the ordinary degree of HRV variation decreased significantly during stress period. The score of HRV fluctuations

at the high frequency (HF) decreased significantly during acute stress, whereas the ratio between low and high frequency significantly increased which suggests sympathetic activation and decrease of parasympathetic activity. In a similar meta-analysis of 37 studies, predominantly a decrease in parasympathetic activity was observed during stress period, which was defined within the HRV parameters as a decline in the high-frequency range (HF) and an increase in the low-frequency range (LF). The meta-analysis also shows the findings of neuroimaging techniques which suggest that HRV might be connected to the function of cortical areas of brain (ventromedial prefrontal cortex) relating to the assessment of stress situations (Kim, Cheon, Bai, Lee, Koo, 2017).

Research done over the past years indicated that meditation might serve as an effective method in confrontation with stress. Scientific publications deal especially with the effectivity of mindfulness meditation which is described as the so-called state of mindfulness, that is, a specific metacognitive awareness, open and non-assessing monitoring of current cognition, emotionality, sensation and perception without clinging to past and future thoughts (Garland, Howard, 2018). Another style of meditation which is also explored by scientists is called concentrative meditation. It is characterized by a deliberate focusing of attention to a mental, sensorial object or activity (e.g. mantra), whereas the individual strives to prevent destabilisation of concentration on the object, inhibit transferring the concentration towards other objects and redirect its focus in the case of distraction from the object causing the distraction to the object of meditation (Hu, Chang, Prakash, Chaudhury, 2011).

Lynch, Prihodova, Dunne, Carroll, Walsh, McMahon a White (2018) compiled in the meta-analysis 37 studies that relate to mantra meditation which is a part of concentrative style. The authors point to methodological shortcomings of the study and differences in length and adherence to intervention, however, partial results indicate that this method might reduce psychological stress, even though it might not be necessarily more effective than other forms of relaxation and stress reduction training. In another meta-analysis of 45 studies the authors concluded that practising of meditation styles that include concentration of attention (concentrative type), open monitoring (mindfulness) a self-transcending style, in comparison to an active control group (physical exercises, relaxation, education), can effect a decrease of physiological stress markers (blood pressure, cortisol, heart rate, levels of cytokines) (Pascoe, Thompson, Jenkins, Ski, 2017).

A study devoted to the immediate effect of mindfulness meditation points to the fact that in patients who underwent a short mindfulness intervention, the cardiovascular reactivity was decreased (decrease of systolic and diastolic blood pressure) and its decline persisted also during exposure to stressor (Steffen, Larson, 2014). Similarly, in individuals with a high level of dispositional mindfulness, undergoing a short mindfulness intervention before accomplishing a stress-inducing task led to a better stress regulation and also a better post-stress recovery with regard to cortisol level, as contrasted to the control group (Laurent, Laurent, Nelson, Wright, Sanchez, 2014). Dispositional mindfulness can be characterized by the capability of the individual to stay calm and accept stressful thoughts and emotions, as well as the ability to observe one´s inner and outer experience, discriminate emotional states and realize the automaticity of processes (Baer, Smith, Hopkins, Krietemeyer, Toney, 2006). Kadziolka, Pierdomenico and Miller (2015) explored in their study the influence of dispositional mindfulness level in connection with self-regulation and stress reactivity. The authors evaluated self-report mindfulness scores and preliminary measurement results of physiological reactivity obtained before, in the course and after the interview relating to a recurring stressful event. The results reveal that individuals with a higher level of natural mindfulness showed parasympathetic activation immediately after accomplishing the task, which lowered the level of subjectively perceived stress. Similarly, individuals with a higher level of dispositional mindfulness showed a deeper physiological recovery after accomplishing an emotionally exhausting task, which was demonstrated by a decrease of HF range of HRV. (Fogarty, Lu, Sollers, Krivoschekov, Booth, Consedine, 2013). Comparably, in students with a higher level of dispositional mindfulness, a significantly lower level of perceived stress and a lower aggregate average of diurnal cortisol were recorded. (Zimmaro, Salmon, Naidu, Rowe, Phillips, Rebholz, Davis, Cash, Dreeben, Veloso, Jablonski, Hicks, Siwik, Sephton, 2016).

From the viewpoint of a longer-term involvement, going through a 10- day intervention of vipassana meditation (mindfulness style of meditation) had a considerably positive psychological effect on the participants, which was demonstrated by the increase of well-being, positive emotions, life satisfaction, mindfulness level and decrease of stress and depression level. In the course of meditation, an increase of HF range (high frequency) within HRV was monitored considering the baseline, which was interpreted as an increase in parasympathetic activity (Krygier, Heathers, Shahrestani, Abbott, Gross, Kemp, 2013). The study that compared a 4-week training of mindfulness meditation and yoga with a control group indicated that active groups achieved the highest HRV level when at rest with a mild decrease when accomplishing a stressful task during yoga whereas during mindfulness, no HRV decrease was observed which denotes to the lowest level of perceived stress (Hunt, Al-Braiki, Dailey, Russell, Simon, 2017). After 6 weeks of mindfulness training, individuals showed an effective and faster emotional and cardiovascular (blood pressure) recovery if recalling a painful, cancer-related memory,

Tab. 1. The difference between the meditative and the control group in normalized meanRR during all the measurement phases: 1: Basal, 2A: Prestress, 2B: Prestress, 3: Stress, 4A: Poststress, and 4B: Poststress (A); the difference between the meditative and the control group in normalized meanHR during all the measurement phases (B); the difference between the meditative and the control group in normalized LF during all the measurement phases (C).

A			B			C		
meanRR	**χ^2 (1)**	***p***	**meanHR**	**χ^2 (1)**	***p***	**LF**	**χ^2 (1)**	***p***
1 Basal	7,202	.007*	1 Basal	7,440	.006*	1 Basal	1,411	.235
2A Prestress	3,919	.048*	2A Prestress	4,095	.043*	2A Prestress	2,108	.147
2B Prestress	4,459	.035*	2B Prestress	4,275	.039*	2B Prestress	4,095	.043*
3 Stress	5,234	.022*	3 Stress	5,234	.022*	3 Stress	0,157	.692
4A Poststress	8,431	.004*	4A Poststress	8,431	.004*	4A Poststress	3,747	.053
4B Poststress	5,855	.016*	4B Poststress	6,290	.012*	4B Poststress	6,288	.012*

* $p < .05$

as contracted to a control group (Croswell, Moreno, Raposa, Motivala, Stanton, Bower, 2017). Attending an 8 week mindfulness program for stress reduction improved the frequency domain of HRV parameters which points to an improved balance of autonomic nervous system with a decrease of sympathetic and increase of parasympathetic activity (Nijjar, Puppala, Dickinson, Duval, Duprez, Kreitzer, Benditt, 2014).

Hatha yoga and training of body consciousness / body scan as elements of mindfulness meditation led to a significantly higher stress and anxiety reduction in undergraduate female students as compared to a control group (Call, Miron, Orcutt, 2013). Through comparison of mindfulness meditation and progressive muscle relaxation, Gao, Curtiss, Liu and Hofmann (2017) pointed to the fact that both interventions led to reduction of stress, and a more in-depth analysis revealed that the changes in emotional state were induced solely by meditation aspects, that is, by a nonreactive observation without assessment. Ford and Shook (2018) in their study demonstrated that mindfulness is associated with a lower negative cognitive bias, which is connected with a lower level of perceived stress and a better psychological well-being. In other words, mindfulness diminishes the subjective assessment of threat by which it reduces stress. According to the findings of a study (Lorello, Haaga, 2015), meditation helps people to observe the internal and external experience by an unbiased approach which leads to constructive coping mechanisms. Apart from this, Garland, Gaylord and Fredrickson (2011) declare in the study that training of mindfulness meditation might in participants induce the state of extended consciousness which facilitates invigorating / uplifting interpretations of stressful life experiences and this leads to a significant distress reduction.

Almost in every study mentioned above, the sample consisted of individuals with a little or no practical experience with meditation and they were only shortly instructed. Consequently, we decided to select people with experience in meditation for the sample, for whom meditation is a part of their everyday life. The aim of our research is to compare Zen (mindfulness) and buddhist (concentrative) meditation training and to evaluate its effect on the heart rate variability and on the level of perceived anxiety before, during, and after the effects of stress. In contemporary scientific literature, only insufficient comparison of effectivity of meditation styles mentioned above is to be found, if we take into account the extent of meditation practice and the related mindfulness level of the individuals. Their effect will be compared also with a control group for the reason of a better evaluation of their effectivity. Considering the study (Erisman, Roemer, 2011), we want to examine the relation between the mindfulness level, HRV and anxiety during stress and the recovery. We suppose that individuals practicing meditation will display a higher HRV level and a lower level of perceived anxiety during the stress and post-stress phase than the control group. Participants in the Zen group will demonstrate a higher level of HVR in stress and post-stress phase than participants in the buddhist group. Our assumption is based mainly on the fact that during Zen meditation, people cultivate their attention which gradually achieves the qualities of acceptance without assessment and nonreactivity that were associated with a better coping with distress (Coffey, Hartman, Fredrickson, 2010; Josefsson at. al., 2011). In contrast to this, concentrative meditation is not directly aimed at cultivation of attention in this way. There is also a question whether the extent of meditation practice or the level of mindfulness will have any influence on HRV parameters in stress and post-stress phase.

Material and methods

Participants

To carry out our research, it was necessary to obtain a sample of people in which individuals would be characterized by average to advanced meditation experiences. In view of the abovementioned criterion, it was necessary to approach meditation centres where similar people

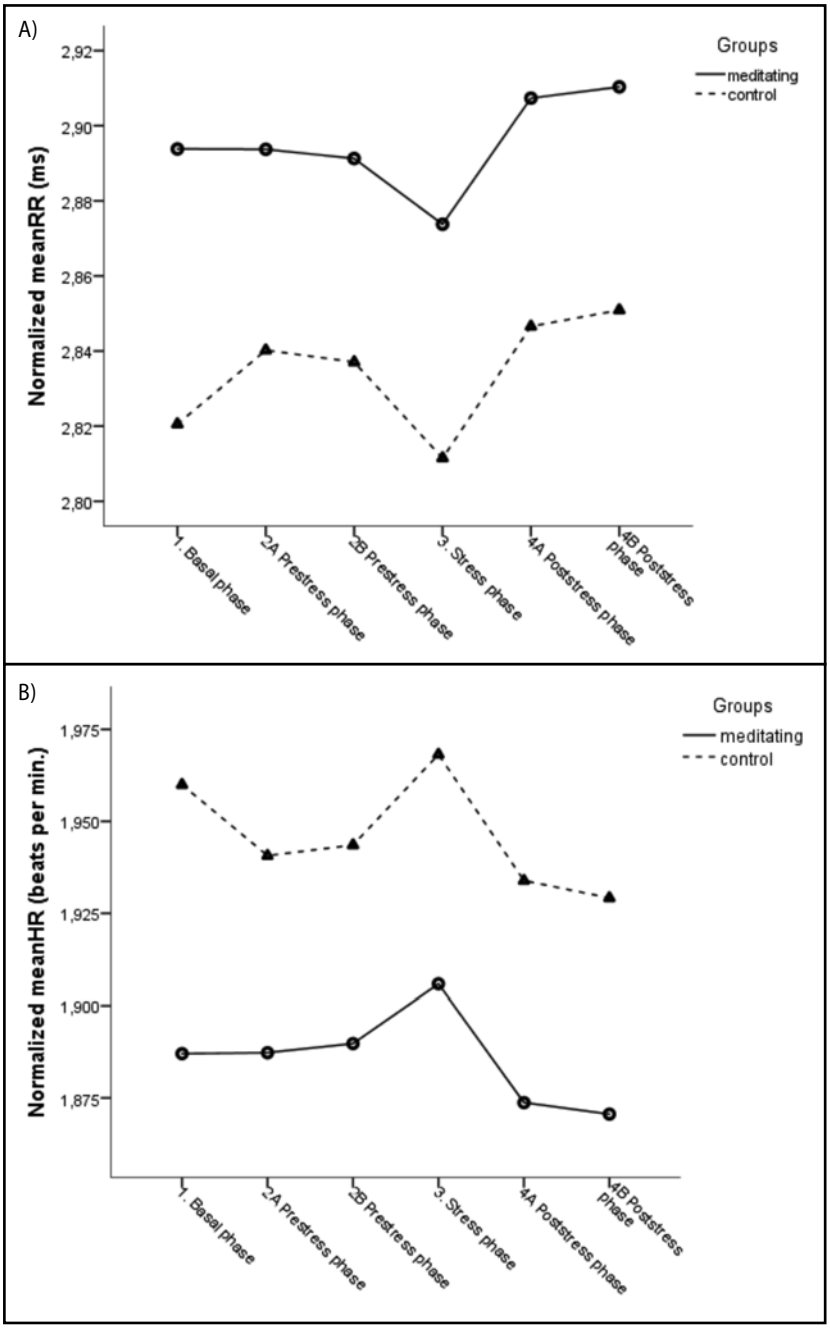

Fig. 1. Differences between meditation and control group in normalized meanRR during all measurement phases (A), differences between meditation and control group in normalized meanHR during all measurement phases (B).

were present. Specifically, we contacted the Diamond Way Buddhism Centre (the karma kagjü line) and the Zen Centre (the Kwanumzen School), both located in Bratislava, Slovakia. Our research sample consisted of N=30 participants, forming three equally large groups. The first group was made up of individuals practising Zen meditation (the Zen group, N=10), of which 7 were men and 3 women. The average age in the group was M_{age} = 32.5 years (SD=10.45, age range=20–52), experience with meditation ranged from 6 months to 28 years (average=9, SD=9.91) with a frequency of 6 times a month to daily. The second included individuals practising Buddhist concentrating meditation based on the 16th Karmapa (The Buddhist group, N=10), of which 3 were men and 7 were women. The average age of the group was M_{age} = 35.6 years (SD=9.24, age range=26–56) and experience with meditation ranged from 6 to 13 years (average=8.9, SD=2.28) with a frequency of 3 to 7 times a week. The third was the control group (N=10) of 2 men and 8 women with an average age of M_{age} = 25.5 years (SD=10.87, age range=19–55) (participants were students). Individuals in this group had to meet the main criterion of not having any previous experience with any meditation exercises.

Tab. 2. The difference between the meditative and the control group in anxiety levels after the individual phases of measurement: 1: Basal, 2: Prestress, 3: Stress, and 4: Poststress

STAI	χ^2 (1)	*p*
1. Basal	3,632	.057
2. Prestress	9,371	.002*
3. Stress	5,294	.021*
4. Poststress	6,382	.012*

* p < .05

Methods

The Applied Mindfulness Process Scale (AMPS) (Li, Black, and Garland, 2015), was used to measure mindfulness level. It is a process-oriented questionnaire that quantifies the frequency at which individuals use meditation skills when faced with problems in common life. Fifteen items represent the three dimensions of the questionnaire: (a) decentralization, (b) positive emotional regulation, and (c) negative emotional regulation. The maximum score is 75, which represents the highest level of mindfulness. It is intended exclusively for individuals who already have experience with meditation, so we did not use it in the control group.

The checklist was focused on self-report evaluation of psychic experiences during the measurement. It consisted of a State-Trait Anxiety Inventory (STAI) questionnaire (Spielberger, 1983) aimed at assessing the level of current anxiety. It was made up of five items, which, according to an analysis by its authors Marteau and Bekker (1992), we selected among others based on their reliability. Example: How are you feeling right now?... "I am calm", "I am tense" (Likert scale – *not at all* = 0, ..., *very* = 4). In addition, it contained several control questions created by us that captured important variables regarding behaviour and experience of the participants, for example: "I was able to fully concentrate on meditation," and "I tried to give the best performance during the task" (in the control questions, two scales were used – [1] from 1 = *not at all*, to 10 = *completely*, represented by emojis, or [2] the same scale as with the shortened STAI).

The heart-rate variability was recorded by an eMotion Faros 90 device (Mega Electronics Ltd, Finland), a non-invasive ECG (Electrocardiography) monitoring system. The frequency of EKG recording was 250-Hz and HRV scanning at 1000-Hz. Individuals had electrodes placed in the Lead II position (the negative pole under the right clavicle, the positive pole on the left in the region of the XIII rib). The data obtained were analysed by Kubios HRV 2.2 software. The parameters we observed in the HRV are as follows:

1. Time domain: meanRR – Expresses the average time (ms) "distance" of RR intervals; SDNN – standard deviation of RR intervals; meanHR – mean heart-rate; RMSSD – the quadratic mean of the differences of the following RR intervals;
2. Frequency (0.04–015 Hz) denotes sympathetic and parasympathetic activity under varying conditions; HF – a high frequency characterizes parasympathetic activity; LF / HF – the low and high frequency ratio measures the overall balance between the sympathetic and parasympathetic nervous system;
3. Non-linear methods: SD1 – this deals with parasympathetic activity (Tarvainen, 2014).

The distraction stress test is a "paper pencil" task that serves to induce cognitive strain and stress. We chose

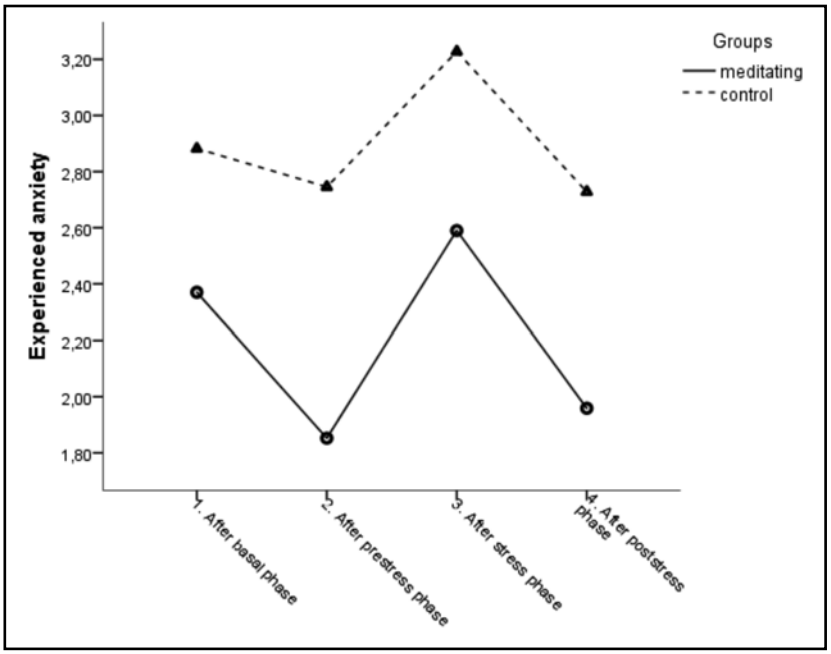

Fig. 2. Difference between meditation and control group at the level of anxiety after the individual phases of measurement: 1. Basal, 2. Prestress, 3. Stress, 4. Post-stress.

Tab. 3. Changes in normalized HRV parameters and anxiety from Prestress B section to Stress phase in Control, Buddhist, and Zen Groups.

	Control group (n=10)		Buddhist group (n=10)		Zen group (n=10)	
	t (9)	*p*	t (9)	*p*	t (9)	*p*
HRV parameters						
meanRR	3,52	.006*	1,22	.25*	1,07	.31*
meanHR	-3,38	.008*	-1,13	.285	-0,99	.346
SDNN	4,69	.001*	5,87	.000*	3,69	.005*
RMSSD	2,4	.039*	3	.015*	1,6	.142
LF	1,09	.304	7,15	.000*	4,18	.002*
HF	3,49	.007*	2,07	.068	1,73	.116
LF/HF	-0,63	.544	0,78	.455	1,87	.094
SD1	2,39	.040*	3,01	.015*	1,59	.144
Anxiety STAI	-2,49	.034*	-2,97	.016*	-9,17	.000*

*significant at $p < .05$

it for our research because of its practicality, but mainly due to its focus on work memory, the strain of which was associated with more significant changes in HRV parameters (Casado *et al.* 2015; Tripathi, Mukundan, and Mathew, 2003). The individual was presented with a text in which, given the perceived low/high tone, they either had to strike through the vowels in each noun or to circle the consonants in each verb. They also had to underline the seventh letter in a sentence that made no sense to them and, when the instructions changed, make a vertical line behind the last marked word.

Meditation and relaxation – Participants in the Zen group practised Zen-seated meditation, the so-called zazen, which has the characteristics of mindfulness meditation, because they deal with the same quality of attention. Participants in the buddhist group practiced the so-called meditation on the 16th Karmapa (author of the meditation) which belongs to the concentrative style. To put it more specifically, the training has the form of guided imagery during which the individual concentrates on the described object, tries to feel its „existence" and the way it interacts with them. The imagery is accompanied also with repeating of mantra. In the control group, progressive muscle relaxation served as an alternative, in the sense of systematic muscle relaxation with the eyes open.

Procedure

Measurements of meditation groups were carried out with their consent on the premises of the centres, and five meetings were needed to obtain the complete data. Our effort was to observe the determined course

Tab. 4. Changes in normalized HRV parameters and anxiety from Stress to Poststress A section phase in Control, Buddhist, and Zen Groups.

	Control group (n=10)		Buddhist group (n=10)		Zen group (n=10)	
	t (9)	*p*	t (9)	*p*	t (9)	*p*
HRV parameters						
meanRR	-7,04	.000*	-2,8	.021*	-3,32	.009*
meanHR	7,03	.000*	2,63	.023*	3,21	.011*
SDNN	-3,42	.008*	-7,71	.000*	-1,97	.079
RMSSD	-2,26	.05	-4,3	.002*	-0,27	.791
LF	-1,68	.126	-5,61	.000*	-2,29	.048*
HF	-1,97	.079	-2,92	.014*	-1,44	.183
LF/HF	0,72	.485	-1,66	.13	-1,64	.134
SD1	-2,26	.05	-4,33	.002*	-0,26	.798
Anxiety STAI	3	.015*	2,4	.039*	-7,71	.000*

* $p < .05$

Tab. 5. Changes in normalized HRV parameters and anxiety from Prestress B section to Stress phase and from Stress to Poststress A section phase in accordance to AMPS distribution (high-low mindfulness).

	Applied mindfulness process scale (AMPS)							
	From prestress to stress phase				From stress to poststress phase			
	High (n=6)		Low (n=6)		High (n=6)		Low (n=6)	
	t (5)	*p*	t (5)	*p*	t (5)	*p*	t (5)	*p*
HRV parameters								
meanRR	-0,00	.993	2,84	.036*	-4,32	.008*	-2,53	.053
meanHR	0,03	.997	-2,77	.039*	3,81	.012*	2,43	.059
SDNN	1,93	.111	6,97	.001*	-2,68	.044*	-4,16	.009*
RMSSD	1,28	.254	3,11	.026*	-0,69	.516	-2,81	.037*
LF	2,54	.051	6,12	.002*	-2,86	.035*	-3,99	.01*
HF	2,25	.074	1,76	.138	-2,12	.087	-2,83	.037
LF/HF	1,03	.349	1,21	.277	-1,84	.125	-0,34	.756
SD1	1,28	.256	3,12	.026*	-0,68	.522	-2,8	.038*
Anxiety STAI	-12,97	.000*	-2,18	.081	2,71	.042*	2	.102

*$p < .05$

of measurement, but also to heed the natural course of particular meditation exercises. Measurement of the control group was carried out in laboratory conditions on the school premises during one meeting.

The experimental design of the research was intra-subject. The specific course of measurement was as follows:

1. Basal phase – at the beginning, individuals in all groups underwent basal ECG measurements with the Faros 90 device for five minutes and then completed the first part of the checklist;
2. Pre-stress phase – all individuals in the individual active groups engaged in the corresponding form of meditation and the control group engaged in relaxation, while the ECG values were recorded by the device for fifteen minutes followed by them completing the second part of the checklist;
3. Stress phase – all participants completed a distraction stress test recorded by the ECG device for five minutes followed by them completing the third part of the checklist;
4. Post-stress phase – in each group the participants engaged in the corresponding meditation/relaxation in individual conditions, recorded by the ECG for fifteen minutes followed by completing the fourth part of the checklist and filling out the AMPS questionnaire (the control group did not fill out the AMPS questionnaire).

Participants switched the device off and on between the individual phases to make them clearly distinguishable. These intervals were used to complete the checklist and follow the instructions and took approximately two to three minutes. The obtained ECG data of individual fifteen-minute phases (2nd and 4th phases) were divided into two five-minute sections (A-initial and B-terminal) to compare ongoing changes in the physiology of different groups and conditions of treatment before and after the effects of the stressor. The total duration of the measured course was approximately sixty minutes; in meditation groups, it was almost ninety minutes. The reason was to maintain the authentic course of meditation exercises – they included singing and other rituals – but these were not inconsistent with measurement and had a negligible influence on the reactions/experience/perception of individuals in relation to it.

Results

All data in the following analysis was checked for normality, and any deviations were corrected. There were no significant differences in HRV parameters and anxiety level among the sexes within any measurement phases.

Differences Between Meditation (regardless of group) and Relaxation (control group) at the HRV and Anxiety Level

The Kruskal-Wallis test was used to identify the HRV parameters and the individual phases in which the averages achieved within the groups were significantly different. The meditators had significantly higher meanRRs and lower meanHRs during all phases of measurement.

The LF in section B of the pre-stress and post-stress phase were significantly higher. The HF in the basal phase was significantly higher as well. In others, they did not differ significantly. Meditators, however, tended to achieve a higher level in all HRV parameters (Table 1, Fig.1).

Subsequently, ANOVA with repeated measurements was used, which in the between-subject effects test pointed to a significantly larger difference between groups in the total achieved average: meanRR – F(1, 14)=7.61, p=.01; meanHR – F(1, 14)=7.55, p=.01; insignificant for LF – F(1, 14)=3,7, p=.064.

According to the Kruskal-Wallis test, a meditating individual also achieved a significantly lower anxiety level after the pre-stress, stress, and post-stress phases (Table 2, Fig.2). ANOVA with repeated measurements in the between-subject effects test pointed to a significant difference between the groups: F(1, 5)=9.74, p=.004.

Changes in HRV Levels and Anxiety for Individual Groups

The differences in mean values within the HRV parameters between the prestress and stress phases were compared using the paired samples t-test (Table 3). Regardless of the group, an overall decrease of HRV was observed in the stress phase. However, the control group showed a significant decrease in almost all the HRV parameters considered: meanRR, SDNN, meanHR, HF, SD1, and RMSSD, expect for the LF and LF/HF. In the Buddhist group, less significantly decreased HRV parameters were recorded: SDNN, LF, SD1, RMSSD, insignificant for meanRR, meanHR, HF, and LF/HF. The Zen group showed the least significant decrease of HRV parameters: SDNN, LF, insignificant for meanRR, meanHR, HF, LF/HF, SD1, and RMSSD. In all groups, the degree of anxiety was significantly increased after the stress phase.

In this case, differences in the mean values obtained within the HRV parameters were compared between the stress and post-stress phases using a paired samples t-test (Table 4). Regardless of the group, an overall increase was observed in HRV. In the Buddhist group, we recorded a significant increase in the largest number of parameters considered HRV: meanRR, SDNN, meanHR, LF, HF, SD1, and RMSSD, and an insignificant increase for LF/HF. In the Zen group there was a significant increase in meanRR, meanHR, and LF, and an insignificant one for SDNN, HF, LF/HF, SD1, and RMSSD. The same number of parameters with a significant increase as in the Zen group was also observed in the control group's meanRR, SDNN, and meanHR, and an insignificant one for LF, HF, LF/HF, SD1, and RMSSD. In all groups, the degree of anxiety after the post-stress phase was significantly reduced.

Level of Mindfulness, HRV, and Anxiety

The Mindfulness Questionnaire (AMPS) was divided into high and low mindfulness before the analysis of this relationship in terms of the gross score achieved: individuals with high mindfulness represented 30% of the highest gross score = high mindfulness; individuals with low mindfulness represented 30% of the lowest gross score = low mindfulness.

Using a paired samples t-test, (Table 5) in AMPS (filled out only by the meditators) was at a low level of mindfulness (N=6, average score=47.6, SD=5.24) and there was a significant decrease of meanRR, SDNN, meanHR, LF, SD1, and RMSSD; at a high level (N=6, average score=67.6, SD=5.16) no significant decrease occurred in any observed parameters. The Kruskal-Wallis test pointed to a significantly lower level of anxiety in high mindfulness after the pre-stress H(1)=4.24, p=.039, and stress phase H(1)=5.13, p=.023.

Discussion

The main objective of our research was to find out how the performance of meditational exercises in direct interaction with a stressor would manifest on the physiological level (HRV) within the individual measurement phases (pre-stress, stress, post-stress). Compared to relaxing individuals, meditating individuals (regardless of the group) had a higher HRV level in almost all parameters and phases. Significant differences appeared in the meanRR and meanHR parameters in all measurement phases, suggesting a lower cardiovascular system responsiveness to stress, the benefits of meditation, and overall lower cardiac strain.

The LF was significantly elevated as well in the B section of the pre-stress and post-stress phase. The increase in LF within the HRV frequency domain in experienced meditators was associated with the discovery of the so-called resonant peak (a high amplitude with a frequency of approximately 0.1 Hz), which represents a high level of concentration and therefore a quality indulgence in meditation. In this state, the different physiological systems are synchronized – the heart, respiratory rhythm and blood pressure (Phongsuphap *et al.* 2007).

The meditators had a significantly higher HF in the basal phase as well. This observation is consistent with previous studies that identified elevated parasympathetic activity in calm conditions in similar subjects (Kodituwakku *et al.* 2012). The achieved level of anxiety was significantly lower in meditators than in the control group, which is consistent with the observed physiological indicators.

Furthermore, we assumed that the Zen and Buddhist groups would exhibit less stress responsiveness than the control group. For all groups, the HRV was reduced, which means that the task we chose for the research successfully induced the necessary level of strain and stress, which manifested in the groups with a significant increase in subjectively perceived anxiety. The control group experienced the largest decrease in HRV. The smallest decrease was recorded in the Zen group. The results are also consistent with previous research that highlighted the preventive effect of mindfulness meditation on reducing cardiovascular reactivity during stress (Steffen and Larson, 2014). A clarification of the results can be found in the way meditators can approach

stressful situations. An important role in this case is played by mechanisms through which meditation works and the qualities it makes available to individuals. Acceptance and non-reactivity to the experience and cognitive emotional regulation strategies such as decentring and positive reappraisal are all significant (Coffey, Hartman, Fredrickson, 2010; Josefsson *et al.* 2011). A particularly positive reappraisal seems to be an important factor of a high level of mindfulness, because it stimulates the individual to change the familiar framework to cognitive, emotional, and behavioural flexibility (Garland, Gaylord, Park, 2009). HRV in this case can serve as a representative of quality self-regulation and not just as an index of a healthy heart function. This assumption is supported by the Neurovisceral Integrative Model of Thayer, Ahs, Fredrikson, Sollers and Wager (2012), which emphasizes the association of different self-regulatory processes (particularly positive reappraisal) with the central autonomous network (an important role is played by the medial prefrontal cortex) that adapts cardiovascular reactivity to changing environmental conditions through the autonomic nervous system, leading to proper adaptation. Therefore, HRV can provide measurable information about the body's capacity to function effectively in a complex environment and its ability to self-regulate.

The Buddhist group showed the best recovery capacity with the greatest increase of HRV. The Zen and control groups achieved similar results. The reason may be due to the fact that the Buddhist group was represented by a more homogeneous and experienced sample than the Zen group in terms of meditation practice. However, due to this fact, the Buddhist group was able to achieve the same level of HRV in the post-stress phase as in the pre-stress, might indicate the high self-regulating ability of individuals. There was no increase in HRV in the Zen and control groups to this extent. However, the level of subjectively perceived anxiety in all groups was significantly reduced.

In terms of the findings, our assumption was not confirmed, as the Buddhist group reached a higher overall HRV level compared to the Zen group and significantly in the post-stress phase. From this perspective, concentrative meditation seems more efficient than mindfulness. Even with mantra repetition in section B of the pre-stress and post-stress phase, it reached a higher level of HRV, despite the previous finding that it was decreasing during its course (Steinhubl *et al.* 2015). The main difference, however, is that in the study mentioned, participants only had a week's worth of meditation training and their previous experience did not have to coincide with a similar exercise. In our study, the participants had a long-standing practice of concentrating meditation, which was reflected in reaching the resonant peak (LF), especially during mantra repetition.

The finding of an association of the level of mindfulness measured by the questionnaire, AMPS, and physiological reactivity (HRV) to stress is noteworthy. The low level of mindfulness showed a significant reduction in HRV in the stress phase, but did not occur at high levels. The reason may be the focus of this questionnaire, the dimensions of which capture the individual's self-regulation ability gained through the effects of meditation. This finding is in agreement and supports the presented model of Thayer and the team. It is possible that the questionnaire identified meditating individuals with a high level of self-regulation, regardless of exercise and meditation practice. As shown in the additional analysis, the correlation between the level of mindfulness (according to the AMPS questionnaire) and meditation practice was insignificant. We can conclude from this that the acquisition of mindfulness qualities can depend on individual abilities. Someone may achieve a certain level within five years, whereas others may achieve it in a year or two. However, this assumption needs to be explored more profoundly.

One of the main limitations of the research is the small research sample, one the reasons being that there is a relatively small number of experienced meditators attending meditation centres. Another reason is the diversity of age distribution in individual groups, which we were not able to fully compensate for. The age representation of the meditating sample in the centres which was varied also played a role. There are also limitations to the various conditions in which measurements have taken place. The measurement of individual meditation groups was performed in different areas with a characteristic course of exercises. Measurement of the control group was performed under controlled laboratory conditions.

Conclusion

In summary, meditation has shown its effectiveness in interacting with stress, managing it, and recovering from it. It has acted not only in the short term as a preventive agent that reduces physiological reactivity, but also in the long-term as a tool for improving and enhancing the internal dispositions of man. Zen (mindfulness) meditation from the physiological perspective showed the best ability to deal with stress, but concentrative meditation overtook it in the recovery phase – achieving the same HRV as in the pre-stress phase. However, both of them surpassed the control group with progressive muscle relaxation by a significant margin. It follows that meditation contains more than just "release", which confirms our findings. In interpreting the beneficial effects of meditation on the HRV level, we have chosen a perspective that links the cognitive strategies of self-regulation – the mental and physiological level – function of brain structures. In particular, the activation of central autonomic network areas has been associated with the regulation of cardiovascular activity. From our point of view, meditation contributes to the development of proper self-regulation, which leads to the

activation of the corresponding brain centres (medial prefrontal cortex and amygdala) that adequately control the heart's activity and ensure the correct adaptation of the organism. We have confirmed this assumption in part at the HRV level. Thanks to the mindfulness questionnaires, we identified meditating individuals who had the lowest reactivity to stress while possessing high levels of self-regulation. We also propose to use imaging techniques such as fMRI in other similar research which would better explore this relationship.

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Compliance with ethical standards

Conflict of interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent

Informed consent was obtained from all individual participants included in the study.

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