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Research Paper

Effectiveness of Mindfulness-based Stress Reduction on Executive Functions in Patients With Hypertension: A Randomized Clinical Trial

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ABSTRACT

Background: Hypertension one of the main risk factors of cardiovascular diseases and premature death worldwide. Researches indicate different cognitive activities and executive functions in cardiovascular and hypertension patients compared to non-afflicted people.

Objectives: Therefore, the purpose of this study was to investigate the effectiveness of mindfulness-based stress reduction (MBSR) on executive functions in patients with hypertension.

Materials & Methods: The present study was a randomized clinical trial based on the pre-test, post-test, follow-up design. The statistical population consisted of all the people with hypertension who referred to Heshmat Heart Hospital in Rasht City, Iran, in 2021. Thirty-four qualified volunteers were included in the study by purposive sampling method and randomly assigned to two groups of MBSR and control. Wisconsin card sorting test (computer version) were the instrument employed in this research; and MBSR sessions were held for 2 months (8 sessions, one 120-minute session each week). The research data were analyzed using repeated measures ANOVA and Bonferroni post-hoc test.

Results: In the pre-test design, there wasn't a difference in the completed categories and perseverative errors, between the MBSR group (2±0.485 and 30.06±6.60) and the control group (2.06±0.659 and 29.88±9.4. In the post-test design, a significant difference in the completed categories and perseverative errors was found between the MBSR group (3.29±0.848 and 20.94±5.71) and the control group (2.18±0.636 and 29.94±8.70); which implies the MBSR group outperformed the control group in Improving executive functions of patients with hypertension. Finally, at the follow-up, all changes were still stable.

Conclusion: MBSR was effective on executive functions of patients with hypertension. Therefore, it is suggested that the mentioned intervention be used in medical centres to improve the cognitive activities of patients with hypertension, so that its positive results include the condition of these patients.

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Introduction

Hypertension is a serious medical condition and the primary cause of cardiovascular diseases and early death around the world [1]. The global burden of disease study showed that hypertension was responsible for the highest years of life lost due to premature death [2]. Extensive use of antihypertensive medications helped the global average blood pressure to remain constant or slightly decrease [3]; on the other hand, the frequency of hypertension in low to middle-income countries has increased [1]. According to various reports, the frequency of hypertension in different locations of the world ranged between 4 to 78 percent. The mean frequencies in the Eastern Mediterranean region and Iran were 29.5% and 22%, respectively [4].

Epidemiological evidence shows that hypertension is a risk factor for dementia onset and cognitive impairment [5-9]. Also, research backgrounds indicated different executive functions and weaker cognitive functions of patients with hypertension compared with individuals without the disease [10-13]. Executive function, also known as executive control or cognitive control, refers to a family of top-down mental processes that individuals require when they must focus and when autonomy or relying on instinct or intuition is insufficient or impossible [14]. These processes are thought to be supported (at least to some extent) by structure within the brain's frontal lobes. There is also a general agreement on the existence of three primary executive functions: Inhibitory control, working memory, and cognitive flexibility, from which prime executive functions, such as logic, problem-solving, and planning, form [14].

Findings of the Honolulu-Asia aging study previously indicated that the relationship between increased blood pressure in middle age and dementia only existed in patients never treated with antihypertensive medication [15]. A recent study, on the other hand, reported that besides the individuals never treated with antihypertensive drugs, patients with treat-resistant hypertension and those whose systolic blood pressure failed to reach the standard value were also exposed to the risk of severe cognitive problems, such as disordered executive functions [16]. Furthermore, antihypertensive drug use, in the long run, considerably exposes individuals to the risk of losing cognitive abilities and mild cognitive impairment compared with individuals with normal blood pressure. However, patients not adhering to treatment face more cognitive issues [11, 16].

Mindfulness-based stress reduction (MBSR) is among the interventions recently applied to a wide range of medical issues to help the condition of patients of different ages [17]. Mindfulness is rooted in Eastern meditative traditions and is often accompanied by formal meditation practice. Mindfulness is called the heart of Buddhist meditation. Nevertheless, mindfulness is more than meditation. It is a state of awareness in nature, which includes conscious attention to one's moment-by-moment experience. In other words, mindfulness is defined as intentional attention to the experiences of the current moment in an acceptable manner and far from judgment [18]. Various studies indicated mindfulness-based interventions (MBIs) as an effective treatment for enhancing executive functions and reducing cognitive and behavioral problems in different patients. MBI also provided potential confidence as a suitable and effective method for medical care [17, 19-21]. According to estimates, MBIs support participants in mindfulness skills (such as self-awareness, attention control, and emotion regulation) and cause them to act more consistently and correctly regarding other determining factors of the disease, including adherence to antihypertensive drugs, diets, exercise, and stress response [22].

Literature reviews indicated cognitive issues and executive function weaknesses in some patients [11]. Meanwhile, most studies focus on the correlations and etiology, or variables related to hypertension and cardiovascular problems of the patients, and ignore the effectiveness of treatments affecting the cognitive features of hypertension patients. Furthermore, even though MBSR is among the well-received treatments for improving cognitive functions in various sample groups, its effect on the executive and cognitive functions of patients with hypertension has not been investigated, and the number of available studies is limited. On the other hand, inconsistent results of studies, including Askari et al. (2023) [23], and Marciniak et al. (2020) [24], who didn't confirm the efficiency of MBIs on the executive and cognitive functions of the patients, add to the necessity of this study. Considering the mentioned discussions, the present study aimed to investigate the efficacy of mindfulness-based stress reduction on the executive functions of patients with hypertension.

Materials and Methods

Study type and population

The current research was conducted as a double-blind randomized clinical trial with a control group based on a pre-test, post-test and two-month follow-up design. The

study population was all patients with hypertension referred to Heshmat Heart Hospital in Rasht City in 2021. Forthy qualified volunteers of this population were included in the study by the purposive sampling method. The sample size was 40 people according to previous similar studies [25-27], and anticipating 30% dropout due to the conditions of the COVID-19 pandemic. Finally, six subjects dropped out during the study. The inclusion criteria were as follows: Primary (essential) hypertension according to the medical record and under routine medical treatment for at least 6 months since the diagnosis, obtaining a score of less than 3, for the component of completed categories in the Wisconsin test, age range of 30-60 years, ability to speak, read and write, informed consent and willing to participate in the research; and exclusion criteria were: Absence of more than two sessions, inability or unwillingness to use computer or internet; unwilling to continue training, participation in courses at the same time or in the last two months, drug and alcohol abuse, severe personality and clinical disorders or suicidal ideation (according to the Minnesota personality inventory (MMPI scale scores from 71 items) and a clinical interview session by a clinical psychologist), recent head trauma and brain injuries or receiving electric shock or special treatment in the last six months (self report).

Study procedure

After receiving the code of ethics and the clinical trial code, it was coordinated with the Heshmat Heart Research Center in Rasht City; the patients were first visited by a cardiologist at the Heshmat Heart Research Center, then they were referred to the researcher, in the same hospital. In the first meeting, for each patient, the purpose and method of conducting the research were explained, and the demographic characteristics and ethical consent forms were completed. The selected people were assigned to two intervention and control groups using the internet randomization method and the allocation concealment was done by using Sequentially numbered, opaque, sealed envelope (SNOSE) by creating a random sequence. Based on the research sample' size, several aluminium envelopes were prepared and each of the created random sequence was recorded on a card and the cards were respectively placed inside the envelope. Also, in order to maintain the random sequence, the outer surface of the envelopes was numbered in the same order. Finally, the envelopes were glued, closed and placed in a box. Starting the work, the envelopes were opened in order and the allocated group of the participants was revealed. Both group completed pre-test for measuring executive functions with the Wisconsin test, then the experimental group went under intervention by a psychologist proficient in MBI. After the completion of the intervention, a post-test was taken, and a follow-up was conducted two months later.

Course description

The first and perhaps the most well-known empirically supported MBI in the treatment of psychological symptoms, used in this study, is MBSR, developed by Kabat-Zinn in the early 1980s. MBSR is an 8-week structured training program, taught in a group way [18, 28]. We used a psychologist expert in mindfulness to teach this course to the participants and the control group did not receive any type of training at the same time. To prevent withdrawal and to ensure that homework was completed, the participants were contacted regularly (once a week) and one day before each session, and the possible benefits of the study were discussed with them and they were encouraged to continue the study. During the 8-week online course synchronous (one 120-minute session each week), a variety of MBSR techniques including awareness of breathing, eating meditation, body scan, and a number of other techniques were taught and practiced. During the sessions, the experiences of the participants were shared in the form of a group discussion about the benefits of mindfulness in lifestyle behaviors related to hypertension. Also, exercises in the format of voice and video were presented to each participant so that they can use them in their daily homework. The adapted summary of MBSR sessions [29, 30] is presented in Table 1.

Measurement tools

In order to collect information, in the first session (screening), the form of demographic characteristics, including gender, age, education level, marital status, employment status, exercise and smoking was completed by the participants as a self-report. Duration of illness, medication status and substance abuse and other physical was checked through clinical interviews and medical record. Also, mental diseases were checked through clinical interviews and MMPI scale scores from 71 items by a clinical psychologist). In addition, height and weight (body mass index) were measured with a digital scale and measuring tape by the first author of the study.

In order to measure the research variable, the computerized standard Wisconsin test was implemented individually in face-to-face sessions.

Table 1. Summary of mindfulness-based stress reduction sessions

Sessions	Object	Exercises
Session 1	Formal practice	• Opening practice (brief, arriving) • Explanation about doing mode & being mode • Body scan
	Informal practice	• Eating meditation
	Home practice	• Body scan, 6 days this week (with recorded voice) • Eat one meal this week mindfully or at least a few bites during one meal. • Optional informal practice ("small doses, many times"): Informally and intentionally notice or cultivate moments of awareness during the day—tuning briefly into the breath, body, sounds, what can be seen, and thoughts and emotions—whatever is present, noticing without judgment; recognizing directly that you can deliberately cultivate a continuity of awareness throughout your day as a way of beginning to access your innate resources for coping and meeting live in ways that are less conditioned and more appropriate to situations you are facing. • Review information about emotion in practice manual or handout.
Session 2	Formal practice	• Opening meditation • Sitting meditation • Yoga - a few postures (optional) • Body scan • Sitting meditation with awareness of breath (AOB)
	Informal practice	• For home practice: Mindfulness of routine activities: Brushing teeth, washing dishes, taking a shower, taking out garbage, shopping, reading to kids, eating (participant chooses one). • Continue including some of the yoga poses into your day. Become aware of repetitive movements in ordinary activities, i.e. getting into and out of the car, preparing meals, bathing children, taking a walk, etc.
	Home practice	• Body scan, 6 times per week (with recorded voice) • AOB sitting meditation: 10-15 minutes per day. Participants/patients are instructed to practice on their own. This is not about controlling or changing the breath, but rather being with the breath and the bodily sensations of breathing, noticing when attention wanders, and deliberately returning attention to the breath. • Fill out pleasant events calendar for the week – one entry per day. Note: If no pleasant event is perceived on a given day, there is no need to fill out the calendar for that day. • Choose one daily activity to bring full awareness to for the week: Brushing teeth, taking out the garbage, taking a shower, feeding a pet, etc.
Session 3	Formal practice	• Opening meditation, which can flow into longer sitting practice of AOB with attention to posture • Mindful lying down yoga. • Walking practice (if time): This practice can be introduced at any time from week three forward – It is strongly recommended that mindful walking be introduced at least one time prior to the all day-class.
	Informal practice	• Mindful attitude (non-judgemental) • Reminder during class discussions (both small and large group) of mindful listening and speaking.
	Home practice	• Alternate body scan with lying-down yoga, every other day, 6 days per week (with recorded voice) • Sitting meditation with AOB - 15-20 min per day. • Fill out an unpleasant events calendar for the week, one entry per day.
Session 4	Formal practice	• Opening meditation • Standing yoga • Sitting meditation • Closing meditation
	Informal practice	• Reminder during class discussions (both small and large group) of mindfully listening and speaking.
	Home practice	• Alternate body scan with lying-down yoga, every other day, 6 days per week (with recorded voice). • Sitting meditation 20 minutes per day with attention to breathing, other physical sensations, and awareness of the whole body • Be aware of automatic habitual stress reactions and behaviors during the week, without trying to change them. • Be aware of feeling stuck, blocking, numbing, and shutting off to the moment when it happens this week. • Review information about stress in practice manual or handout.

Wisconsin card sorting test (computer version)

Grant and Berg (1948) introduced the Wisconsin card

Sessions	Object	Exercises
Session 5	Formal practice	• Opening meditation • Yoga • Sitting meditation (the longer, full sit is offered, including all five objects of awareness and more silence)
	Informal practice	• Mindful attitude (acceptance and letting go) • Reminder during class discussions (both small and large group) of mindfully listening and speaking.
	Home practice	• Sitting meditation and standing yoga sequence. Alternate sitting meditation with standing yoga and either body scan or lying down yoga (for example: One day practice sitting meditation, the next, practice standing yoga, the third day practice sitting meditation, the fourth day, practice the body scan, etc.). • Fill out difficult communications calendar. • Bring awareness to moments of reacting and explore options for responding with greater mindfulness, spaciousness, and creativity in formal meditation practice and in everyday life. Remember that the breath is an anchor, a way to heighten awareness of reactive tendencies, to slow down and make more conscious choices.
Session 6	Formal practice	• Sitting meditation • Mindful seeing and listening • Closing meditation
	Informal practice	• Reminder during class discussions (both small and large group) of mindfully listening and speaking
	Home practice	• Alternate Sitting Meditation with Body Scan and/or Standing or Lying down Yoga (with recorded voice)
Session 7	Formal practice	• Sitting meditation options: Mountain, lake or loving-kindness • Other options: Yoga (class choices), window, walking
	Informal practice	• Reminder during class discussions (both small and large group) of mindfully listening and speaking.
	Home practice	• Practice formal sitting, yoga, walking and/or the body scan on your own, every day for 45 minutes (with recorded voice). • Practice informally when you are not doing the above formal practices by being as aware and awake as possible throughout the day.
Session 8	Formal practice	• Body scan • Yoga • Sitting meditation
	Informal practice	• Reminder during class discussions (both small and large group) of mindfully listening and speaking.
	Home practice	• Go back to what you have learned, if you wish. Keep up the practice and make it your own. • Continue to work with bringing seamless attention to all your moments in order to be more present in your life.

sorting test [31], and then Heaton et al. developed the computer version in 1993 [32]. This test is among the primary indicators for determining the function of the brain's frontal lobes and the most common test for evaluating executive functions [33]. This tool includes four primary cards (including a triangle, star, cross, and circle), constantly displayed on top of the monitor display until the end of the test. Sixty other cards in random order appear at the bottom of the display, one after another. When a card is displayed on the monitor, the participant must decide that considering the three parameters (i.e. color, shape, number), this card must be placed under which of the primary cards. The display monitor instantly shows the correct or wrong feedback after the participant's response. The intended pattern changes after ten successive correct answers by the participant [33]. The Wisconsin exam has several outputs and scoring methods. The most common grading method is to record the number of completed categories and perseverative errors. The number of completed categories which range from 0 to 6, refer to the number of correct courses or in other words ten consecutive correct answers. A Perseverative Error is recorded when one continues to categorize according to a previously successful principle (regardless of incorrect feedback) and also when, in the first series, they persist in categorizing based on an initial incorrect guess. The range of perseverative errors' score can be between 0 and 60. Obtaining a higher score in the completed categories, as well as a lower score in the Perseverative Errors, indicates a person's better executive functions [33]. In the present study, two outputs of completed categories and perseverative errors were re-

ported. The validity and reliability of this test, has been confirmed in many studies around the world. Kopp et al. (2021) reported the reliability of this tool using Cronbach's α method as 0.95 [34]. In Iran, Shahgholian et al. (2012) designed and assessed the psychometric properties of the computer version of the Wisconsin card sorting test. Differential validity was investigated using two groups of low anxiety and high anxiety, and the result of the test was 2.56 for the completed categories component, and 1.99 for the perseverative errors component, which distinguished the two groups well. The reliability coefficient using Cronbach's α method for completed categories and perseverative errors were 0.73 and 0.74, respectively, and the reliability coefficient using the split-half method was 0.83 and 0.87, respectively [33].

Statistical analysis

Mean±SD were used to describe data. To determine the normality assumption of dependent variables distribution, skewness and kurtosis were investigated. Chi-square and t-test were used to compare variables between the two groups. Mauchly's test was used to check the sphericity or equality of variance of the differences among the research variables levels; also, the M-box test was used to check the assumption of homogeneity of the covariance matrices; and the Leven's test was used to check the equality of variances. To check the hypotheses, repeated measures analysis of variance (ANOVA) and Bonferroni post-hoc test were used. Data were analyzed in SPSS software version 26 at a significance level of 0.05.

Results

Out of 40 eligible patients, 17 were completed the study and were analysed. The Flow diagram of the study is shown in Figure 1. No significant difference was observed between the groups in terms of age (t=0.493, P=0.921), Gender (χ^2=0.119, P=0.730), and body mass index (t=0.772, P=0.595). There was also no significant difference between the groups in terms of education level, marital status, employment status, smoking, exercise, duration of the disease and disease' family history. Table 2, shows demographic variables of the study and Table 3 shows the descriptive information of the research variables.

The findings showed that in the pre-test, there wasn't a difference in the completed categories, between the MBSR group (2±0.485) and the control group (2.06±0.659). In the post-test, a significant difference in the completed categories was found between the MBSR (3.29±0.848) and the control group (2.18±0.636); which implies the MBSR group outperformed the control group in increasing completed categories. Finally, at the follow-up, all changes were still stable in the MBSR group (3.12±0.485) and the control group (2.12±0.600). In the pre-test, there wasn't difference in the Perseverative errors, between the MBSR (30.06±6.60) and the control group (29.88±9.41); In the post-test, a significant difference in the Perseverative errors was found between the MBSR (20.94±5.71) and the control group (29.94±8.70); which implies the MBSR group outperformed the control group in decreasing Perseverative errors. Finally, at the follow-up design, all changes were still stable in the MBSR group (20.88±5.48) and the control group (29.41±8.08).

The degree of skewness and kurtosis of the research variables was in the range of 2 and -2, which indicates the normal distribution of the mentioned variables scores. The assumption of homogeneity of variance was met using Leven's test in the post-test and follow-up phase (P>0.05). Considering the significance of the Mauchly's test result, which indicates the heterogeneity of covariance matrix between the groups, the Greenhouse-Geisser correction was used. The observed interaction effect of group and time was significant for both components of completed categories (F=39.35, P=0.001) and perseverative errors (F=149.97, P=0.001) indicating a significant difference between the groups in terms of the mentioned variables at different times. Therefore, the results of each group was separately assessed over time. The results of pairwise comparison is shown in Table 4. In the experimental group, the mean difference between pre-test and post-test, and between the pre-test and the follow-up for the completed categories' component, has been reported as negative, which indicates a significant increase in the score of the completed categories of executive functions in the post-test and follow-up stages compared to the pre-test in the experimental group (P<0.001). Also, the average difference between pre-test and post-test, and between the pre-test and the follow-up, has been reported as positive for the perseverative errors' component, which indicates a significant decrease in the score of perseverative errors of executive functions in the post-test and follow-up phases compared to the pre-test in the experimental group (P<0.001); while none of the mean differences in the control group were reported to be significant. Therefore, the research hypothesis was confirmed and MBSR was effective in improving executive functions in patients with hypertension.

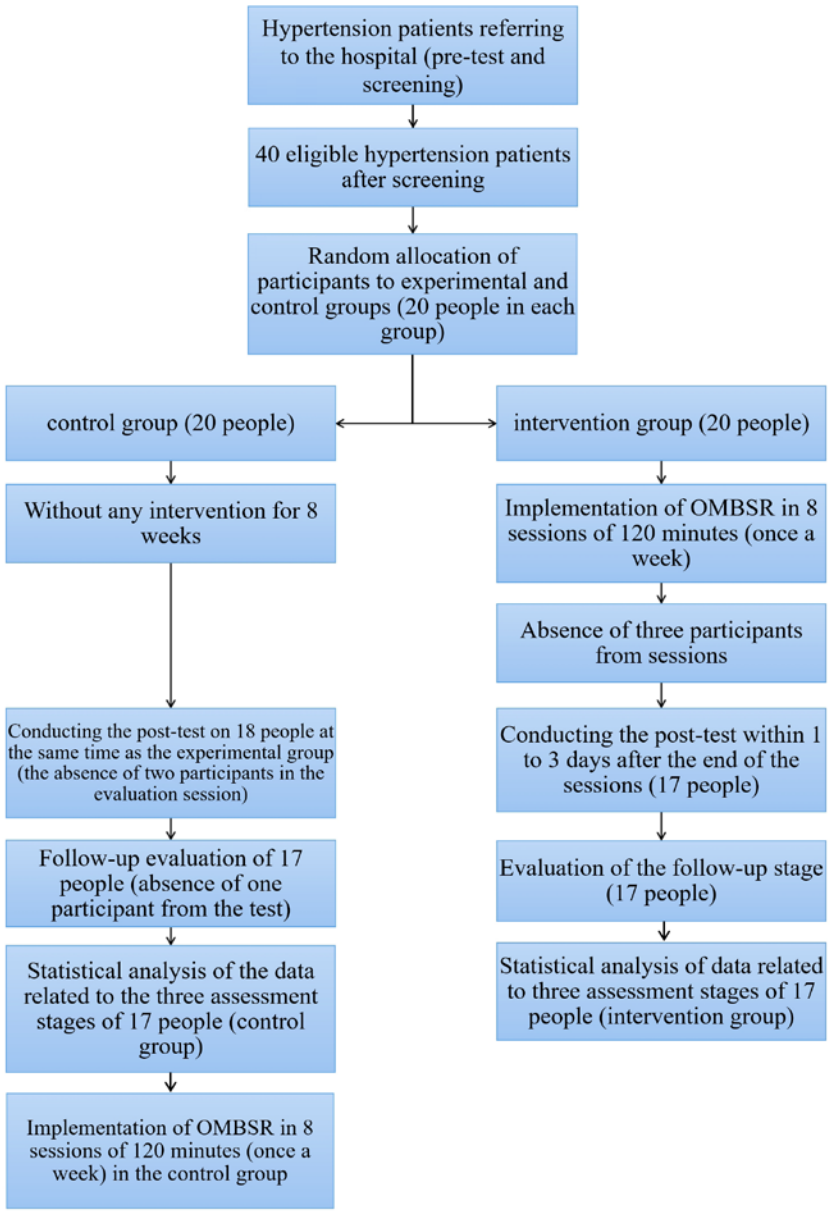

Figure 1. CONSORT flow diagram

Discussion

The purpose of this study was to investigate the effectiveness of mindfulness-based stress reduction (MBSR) on executive functions in patients with hypertension. Results indicated that MBSR significantly improved executive functions in patients with hypertension. In other words, MBSR increased the score of the completed categories, and decreased the score of perseverative errors of the participants in the experimental group. These results are consistent with the results of studies by Eskandari et al. (2022) [35], Shakib et al. (2021) [36], Dong et al. (2023) [19], Yousefi et al. (2023) [21], Ahmed Aboalola (2023) [20], and Zainal & Newman (2023) [17], which showed interventions based on mindfulness led to increasing and improving the executive functions in patients. Ahmed Aboalola's (2023) study showed that it is possible to enhance executive function skills using mindfulness-based intervention in young with attention-deficit/ hyperactivity-disorder (ADHD) [20]. This result was confirmed in the study of Shakib et al. (2021) with the group of children with ADHD [36]. Also, Yousefi et al. (2023) [21] reported that MBSR was effective in promoting executive function in patients with rheumatoid arthritis; and Eskandari et al. (2022) showed the effectiveness of MBI on the executive functions of patients

Table 2. Demographic characteristics of the experimental and control groups

Variables		No. (%)		χ^2	P
		Mindfulness	Control		
Education	Below diploma	12(70.6)	8(47.1)	2.400	0.494
	Diploma	3(17.6)	7(41.2)		
	Associate & Bachelor	1(5.9)	1(5.9)		
	Master & PhD	1(5.9)	1(5.9)		
Marital status	Single	1(5.9)	1(5.9)	0.183	0.913
	Married	13(76.5)	12(70.6)		
	Separated	3(17.6)	4(23.5)		
Duration of Illness (y)	1-5	6(35.3)	4(23.5)	0.568	0.753
	5-10	6(35.3)	7(41.2)		
	>10	5(29.4)	6(35.3)		
Family history	No	5(29.4)	6(35.3)	0.134	0.714
	Yes	12(70.6)	11(64.7)		
Job status	Housekeeper	6(35.3)	3(17.6)	1.867	0.601
	Retired	2(11.8)	3(17.6)		
	Employee	2(11.8)	4(23.5)		
	Free	7(41.2)	7(41.2)		
Smoking	Never	10(58.8)	9(52.9)	0.653	0.722
	Formerly	4(23.5)	6(35.3)		
	Now	3(17.6)	2(11.8)		
Exercise	No	7(41.2)	8(47.1)	0.119	0.730
	Yes	10(58.8)	9(52.9)		

Table 3. Mean±SD of the research variable in the experimental and control groups

Variable of Executive Functions	Group	Mean±SD		
		Pre-test	Post-test	Follow-up
Completed categories	Mindfulness	2±0.485	3.29±0.848	3.12±0.485
	Control	2.06±0.659	2.18±0.636	2.12±0.600
Perseverative errors	Mindfulness	30.06±6.60	20.94±5.71	20.88±5.48
	Control	29.88±9.41	29.94±8.70	29.41±8.08

Table 4. Pairwise comparison of research variables overtime according to the experimental and control groups

Variables (Executive Functions)	Course	Mindfulness			Control		
		MD	SE	P	MD	SE	P
Completed categories	Pre-test/Post-test	-1.294	0.114	0.001	-0.118	0.081	0.490
	Pre-test/Follow-up	-1.118	0.118	0.001	-0.059	0.104	1.000
	Post-test/Follow-up	0.176	0.128	0.563	0.059	0.059	0.997
Perseverative errors	Pre-test/Post-test	9.118	0.373	0.001	-0.059	0.473	1.000
	Pre-test/Follow-up	9.176	0.487	0.001	0.471	0.595	1.000
	Post-test/Follow-up	0.059	0.201	1.000	0.529	0.273	0.210

MD: Mean difference; SE: Standard error.

with multiple sclerosis [35]. Askari et al. (2023) [23], and Marciniak et al. (2020) [24], conveying inconsistent results with the present hypothesis, showed that MBSR had a minimal impact on cognition and reported no statistically significant difference. However, when describing their results, they mentioned the low adherence of their participants to home exercises.

In the explanation of the present hypothesis, the neurological mechanisms of the effect of MBIs are first discussed. For instance, Fornix, located at the mesial aspect of the cerebral hemispheres, connects several knots of the Limbic system and plays critical roles in cognition and episodic memory recall [37]. Polcari et al. (2022) reported that individuals under MBIs indicated increased axial diffusivity in the fornix-stria terminalis tract at the right side compared with the control group, which showed increased structural connectivity. Brain imaging also revealed a thicker corpus callosum in meditators, indicating greater structural connectivity [38]. Also, Sperduti et al. (2012) presented a meta-analysis study on brain regions activated during mindfulness training. They found that the basal ganglia, entorhinal cortex, and medial prefrontal cortex are important brain regions activated during mindfulness. These three regions are critical to the cognitive and emotional processes involved in mindfulness training. They found that when people are in a state of mindfulness, the basal ganglia can help inhibit irrelevant thoughts, the entorhinal cortex helps control mental state, and the medial prefrontal cortex helps increase emotional awareness [39]. All the mentioned cases such as memory, inhibitory control and self-awareness are dimensions of executive functions on which the effectiveness of mindfulness therapy was also shown in the present study.

According to a study by Laneri et al., (2016) MBI was related to structural changes in the cingulate because changes in white matter structure in the posterior cingulate cortex were observed in experienced meditators [40]; also, Tang et al. (2012) reported changes in white matter in the anterior cingulate cortex of experienced meditators, smokers, and healthy individuals who participated in MBIs [41]. Furthermore, studies on the electroencephalography of experienced meditators highlighted the creation of certain brain rhythms involved in consciousness and metacognitive perception, including changes in gamma waves, whose range primarily depends on the number of exercise hours [42].

In another explanation, MBI is a psychotherapy in which individuals learn the mental representation of issues in life that are beyond immediate human control through breathing, acceptance, and non-judgmental viewing [43]. In other words, response occurs when the mental pathways of response generation are sufficiently stimulated. Accordingly, reinvestment of non-automatic attention and non-habitual response, which can be facilitated by MBSR, is necessary for the improvement of MBSR tasks [36]. Another explanation is that according to the opinion of Muller et al., relaxation exercises improve the function of primary hormones (which play critical roles in the physiology of mood disorders) by improving the circulation in endocrine glands and indirectly affect executive functions by improving the mood [44]. According to the authors of this study, mindfulness exercises have a lot in common with executive functions; that is, in all mindfulness exercises, components of executive functions such as attention and working memory are involved. For example, the basic concepts of mindfulness therapy, i.e. explaining doing mode and being mode, teach the participant how to perform a non-automatic, conscious task; or in a body scan exercise, people pay attention to

bodily sensations in different parts of the body, refocusing if they get distracted. Also, in breathing meditation, the focus is on breathing, and participants are encouraged to return to the practice of focusing on breathing with the concentration on the inhalation and exhalation of their breath if their mind distraction. In other exercises such as eating, seeing and hearing meditation, paying attention to experiences in the present moment and focused and expanded awareness is the basis of the work. And this is the skill that involves people's executive functions when doing things. Therefore, as the muscles of the body gain more strength due to continuous exercises, it is not unlikely that frequent mindfulness exercises improve executive functions. In spite of conflicting findings, most of studies are generally well suggesting that MBSR can improve executive functions and cognitive aspects which have important roles in maintaining self-care and treatment adherence in chronic patients.

Conclusion

According to the results of this research, MBSR was effective on executive functions of patients with hypertension. Therefore, it is suggested that the mentioned intervention be used in medical centers to improve the cognitive activities of patients with hypertension.

The current research faced some limitations. Although we tried to comply with all of the clinical trial requirements, due to the special conditions of COVID-19, we were faced with a sample limitation and we used the Purposive sampling method (although the allocation of groups was random), so the small sample size and the non-random nature of the sampling may make it difficult to generalize the findings. The follow-up period was only two months which does not guarantee long-term sustainability. Another limitation of the present study was the lack of a comprehensive investigation on the type and dosage of the drugs used by the participants, which may cause significant and considerable effects on the executive and cognitive functions of the patients. With regard to the limitations of the current research, it is suggested to consider the mentioned cases in future researches.

Ethical Considerations

Compliance with ethical guidelines

This article was approved by Department of Psychology, Tabriz Branch, Islamic Azad University (Code: IR.IAU.TABRIZ.REC.1400.02) and was registered by the Iranian Clinical Trial System (IRCT) (Code: IRCT20210531051454N1).

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Authors' contributions

All authors equally contributed to preparing this article.

Conflict of interest

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