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The effectiveness of mindful self-compassion training on difficulties in emotion regulation and cognitive flexibility of mothers of children with phenylketonuria

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Abstract
Phenylketonuria is a genetic disorder that affects a rare number of individuals. The metabolic and psychological issues associated with this condition can leave mothers of PKU children vulnerable to negative emotional reactions. To address this, the goal of this study was to investigate the effectiveness of Mindful Self-Compassion on difficulties in emotion regulation and cognitive flexibility in these mothers. The study utilized an experimental research design employing a pretest–posttest control group approach, with a follow-up period of 3 months. The participants consisted of 30 mothers who had children with Phenylketonuria and were receiving support services and dietary products from the Metabolic Patients Support Institute of Zanjan Province, Iran. Fifteen participants underwent an 8-week Mindful Self-Compassion program based on a specific protocol, while the remaining 15 served as the control group. The study assessed changes in difficulties in emotion regulation and cognitive flexibility at the pre and post-training stages, as well as at the follow-up stage. The data was analyzed through the employment of repeated measures analysis of variance, followed by the Bonferroni post hoc test. The results showed that the mean scores of the experimental group's total difficulties in emotion regulation and cognitive flexibility changed in the post-training and follow-up stages compared to the pre-training. ($P \leq 0.001$). However, after the training, the scores of the components of Nonacceptance and Impulse did not change significantly ($P > 0.05$). The results suggest that MSC can effectively reduce difficulties in emotion regulation and improve cognitive flexibility among mothers of children with PKU. However, Additional research is required to ascertain whether MSC provides particular advantages for certain kinds of emotional regulation difficulties.

Keywords Mindfulness · Self-compassion · Cognitive flexibility · Emotion regulation · Phenylketonuria

Introduction

Phenylketonuria (PKU), a metabolic disorder present at birth, arises from a shortage or malfunction of the phenylalanine hydroxylating enzyme, leading to the inability to convert phenylalanine (PHE) into tyrosine. If left undiagnosed and untreated, the condition can lead to the build-up of PHE in the blood, resulting in neurological disorders, Intellectual disability, and seizures. Additionally, behavioral problems such as aggression, hyperactivity, and autistic-like behaviors may occur (Etemad et al., 2020). The primary treatment for PKU involves following a low-protein diet, which helps to maintain PHE levels within a specified range and prevent neurological complications associated with the disease (Carpenter et al., 2018).

Continuous monitoring of protein intake per day, frequent tests to measure blood PHE levels, lack of access to phenylalanine-free foods, cognitive and learning disabilities, and economic problems all complicate the treatment, requiring more time and exerting a great deal of energy on the part of the patients and their family (Fidika et al., 2013). Therefore, the birth of a child with PKU, directly and indirectly, affects the lives of children and caregivers and changes their normal life routines. Parents of these children experience physical problems, fatigue, and some degree of psychological reactions, such as confusion, anger, frustration, impatience, feelings of worthlessness, guilt, and concerns about the child's health (Gunduz et al., 2015). This

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stressful period can create a negative attitude and difficulty in regulating emotions in parents, especially mothers, and consequently, affect the child's treatment regimen. Therefore, mothers of these children need a wide range of cognitive and emotional regulation (ER) skills to manage their stress and control the child's diet therapy (Fidika et al., 2013).

Difficulties in emotion regulation (DIER)

ER pertains to the internal and external processes that are involved in managing, regulating, assessing, and adapting emotional reactions, particularly the transient and intense properties, to accomplish one's objectives (Grezellschak et al., 2015). Difficulties in ER include challenges related to awareness, perception, and acceptance of emotions, limited access to optimal strategies for managing different emotions, and difficulty controlling behavior in response to intense emotional stimuli (Gratz & Roemer, 2004). Research has demonstrated that emotional disorders or dysfunctional ERs play a significant role in a broad range of psychiatric disorders, such as anxiety and depression (Schneider et al., 2018). Through a review of 114 studies, Aldao et al. (2010) explored the link between dysfunctional ER strategies and psychopathology. They concluded that strategies such as mental rumination, suppression, and avoidance of problem-solving can have a substantial influence on the emergence of psychological disorders. Megreya et al. (2020) indicated that mothers of autistic children exhibited elevated levels of anxiety and depression and utilized less positive reappraisal, positive refocusing, and reconsidering planning. It is also worth noting that. The challenges faced in adapting to emotional experiences could potentially play a role in the psychological difficulties encountered by mothers of children with neurodevelopmental disorders.

Cognitive flexibility (CF)

In addition to the psychopathology that can result from various environmental stressors, such as having a sick child, CF has emerged as a critical issue. It is one of the important dimensions of cognitive functions and one of the most critical components of executive functions, which relates to a person's ability to modify thoughts, actions, and solutions in response to changing circumstances. To exhibit flexible cognition, individuals must be able to activate and modify their cognitive processes in response to requests for change in activity or instructions for performing an activity (Logue & Gould, 2014).

Furthermore, psychological flexibility includes six components: 1. Acceptance: considering inner experiences without judging them 2. Detachment: separation from inner thoughts and experiences 3. Mindfulness: being in the moment 4. Self as context: observing self, 5. Values 6. Committed action. Psychological flexibility is in the form of real-time communication, full awareness of feelings, emotions, and thoughts, including unwanted experiences, and welcoming them, which enables movement to determine and achieve individual values (McCracken & Morley, 2014).

Furthermore, Psychological flexibility involves being present and accepting our thoughts and feelings, while aligning our actions with long-term values instead of giving in to short-term impulses, thoughts, and feelings, which often stem from avoiding personal experiences and an attempt to control unwanted internal events (McCracken & Morley, 2014). Individuals who demonstrate flexible thinking, tend to use possible explanations, reframe their thought patterns positively, and approach demanding situations or tough events with adaptability and resourcefulness. Additionally, people who have CF demonstrate greater resilience and tolerance than those who lack it. In contrast, individuals who lack CF tend to experience disturbing thoughts and feelings when faced with critical and stressful situations, and they may struggle to find alternative coping methods to alleviate these feelings (Hulbert-Williams et al., 2015).

Research findings suggest the significant role that CF can play in reducing anxiety, depression, and stress, as well as improving mental well-being, enhancing the quality of life, as well as increasing satisfaction with life (Lennard et al., 2021).

According to Woodruff et al. (2014), There is a strong negative link between psychological inflexibility, self-compassion, mindfulness, and the indicators of depression and anxiety. Similarly, the research conducted by Safari Mousavi et al. (2019) in Iran revealed a negative link between psychological flexibility and anxiety, depression, and stress in individuals with type II diabetes. Thus, individuals who utilize adaptive ER strategies and exhibit greater psychological flexibility tend to experience less depression, anxiety, and stress.

Self- compassion(SC) and mindfulness

As mentioned earlier, parents, especially mothers of children with PKU, face difficulties concerning their child's illness. The way individuals handle stressful events can be influenced by their unique personality traits and potentially mitigate some of the negative effects of severe stress. One effective strategy for adapting to and regulating changes in the emergence, intensity, or continuity of emotions resulting from stressful life events is the practice of SC (Shenaar-Golan et al., 2023). SC facilitates emotional change to care for and support oneself in difficult life situations, which weakens self-attack, increases self-acceptance, and reduces emotional turmoil. It thus enables the individual to be more relieved and healed (Gilbert, 2017). Similarly, mindfulness

along with attention to and acceptance of personal suffering is one of the necessary conditions for developing SC (Neff & Germer, 2013).

SC and mindfulness are intertwined and serve as powerful internal resources for coping and resilience in the face of stressful life circumstances, including trauma, negative social evaluation, and the ability to reset goals after experiencing failure (Neff & Faso, 2015). According to Wong et al. (2016), SC can help parents of autistic children cope with the stigma and psychological distress they experience. In Iran, studies conducted in the field of interventions based on compassion and mindfulness indicated the impact of these interventions in enhancing CF, psychological well-being, and life expectancy in Human Immunodeficiency Virus (HIV)–infected patients (Amirkhani et al., 2021; Khalaj et al., 2020), decreasing psychological symptoms, and improving the regulation of emotions in mothers of attention-deficit hyperactivity disorder (ADHD) children (Navab et al., 2019). In addition, the compassion-focused therapy-based intervention for parents was effective in reducing anxiety, aggression, and problematic behaviors in their children (Abdolali et al., 2023).

MSC specifically focuses on cultivating the SC concept, that is developed by Neff and Germer (2013). MSC is a three-part model that includes self-kindness, common humanity, and mindfulness instead of self-judgment, isolation, and over-identification (Neff & Germer, 2013). MSC promotes an adaptive self-relationship that fosters awareness and acceptance of difficult experiences, self-kindness during times of difficulty, and the ability to see life challenges as a universal experience. Yet, the absence of SC and mindfulness might cause individuals to react to difficult emotions by avoiding them, overly identifying with them, or blaming and judging themselves (Germer & Neff, 2019). An expanding body of research supports the notion that supporting the effect of MSC in promoting SC and other facets of psychological well-being. Randomized controlled trials have shown that MSC significantly impacts SC, mindfulness, compassion towards others, and overall life satisfaction. At the same time, it effectively reduces symptoms of stress, anxiety, emotional avoidance, depression, and excessive thinking (Bluth et al., 2016; Neff & Germer, 2013). According to Neff (2023), individuals who participated in MSC training experienced notable improvements in their levels of SC and happiness, while also experiencing reductions in stress, depression, and excessive thinking.

Purpose of the study

Mothers of children with PKU often experience stress, difficulty regulating negative emotions, and challenges adjusting to new demands related to their children's care and treatment (Carpenter et al., 2018). Children's neuro-cognitive problems, as well as food prohibition, children's refusal of alternative protein, lack of access to special dietary products, and high responsibility burden, including controlling the optimal amount of PHE and frequent blood sampling, make mothers with children with phenylketonuria susceptible to mental disorders. or psychological distress (Fidika et al., 2013). These people have a vulnerable personality because they consider themselves responsible for the conditions created for their children or feel that they are not able to take care of their children properly (Etemad et al., 2020).

However, studies show that mindfulness and SC have a protective role against emotional distress, including stress, depression, and anxiety, and improve ER as well as mental well-being. In addition, compassionate people may have more emotional resources available to successfully overcome difficult life challenges (Neff & Faso, 2015; Neff & Germer, 2013).

According to this evidence and the necessity of intervention measures and support programs to reduce the psychological distress of mothers with PKU children, it seems that the MSC program can be effective in empowering parents to face the problems of PKU disease.

The MSC training program, developed by and Germer and Neff (2019), was used in this study to investigate its effectiveness on DIER and CF among mothers of children with PKU. Drawing from previous research, this study seeks to test two hypotheses as follows:

Hypothesis 1: The MSC training will reduce their levels of DIER and its dimensions.
Hypothesis 2: The MSC training will experience a rise in their amount of CF.

Methods

Participants

The study employed an experimental design involving pretest–posttest measurements, a control group, and a follow-up period of three months. The target population comprised 88 mothers who had PKU children and were receiving care from the Association for the Protection of Metabolic Children in Zanjan, Iran in 2022. Participants were selected based on medical diagnosis and meeting the inclusion criteria.

The study sample size was 15 participants per group, based on Cohen's table for experimental studies (Cohen, 1988), With a 95% level of confidence, an effect size of 0.70, and a test power of 0.91. Therefore, 30 eligible and willing mothers who had children with PKU, received dietary products lacking phenylalanine and supportive services from

the metabolic center of Zanjan province. Participants were recruited using convenience sampling and then randomly assigned to either the experimental (Exp) or control(Cont) group.

The inclusion criteria for the study were:

- Registration of medical records for a child with PKU
- Recipient of dietary products without phenylalanine and support services from the Institute for the Protection of Metabolic Children in Zanjan province
- Age range between 20 to 50 years
- Possession of a minimum high school education
- Not receiving psychological services or individual counseling outside of the study
- Voluntary participation and taking informed consent
- Demonstrated commitment and interest in attending the training sessions regularly.

The following were the exclusion criteria:

- Declining to continue participation
- Having medical diseases such as COVID-19, asthma, and allergies, and
- Absence of more than two sessions in the intervention session.

Instruments

Demographic information questionnaires In addition to the standardized measures, a researcher-developed questionnaire was used to collect demographic and clinical data, such as the participant's age, developmental period of the child, and their child's treatment status (diagnosis at birth or late diagnosis), place of residence (town or village), and any other physiological or psychological problems experienced by their child with PKU, such as mental retardation, epilepsy, aggression, hyperactivity, autism, weakness, muscle paralysis, and so on.

The cognitive flexibility inventory (CFI) CFI is a self-report scale comprising 20 items designed to assess the adaptive, alternative, balanced, and appropriate thinking abilities of individuals who face challenging life events. The CFI consists of two sub-scales: perception of different options (13 items) and controllable perception (7 items). Respondents rated their level of agreement with 20 statements related to CF using a 7-point Likert scale, with 1 representing strongly disagree and 7 representing strongly agree. More scores on the CFI mean greater CF. The concurrent validity of the CFI with the Beck Depression Inventory-II (BDI-II) was 0.39, while its convergent validity with the CF of the scale of Martin and Robin (1995) was 0.75 (Dennis & Vander Wal, 2010). The internal consistency reliability of the CFI was assessed using Cronbach's alpha method. The coefficient obtained was 0.91 for the entire scale, 0.84 for the controllable perception subscale, and 0.91 for the perception of different options subscale. The test–retest method was also used, resulting in reliability coefficients of 0.81 for the whole scale, 0.77 for the controllable perception subscale, and 0.75 for the perception of different options subscale. In a previous study conducted in Iran by Shareh et al. (2014), the reliability coefficient for the entire scale was reported as 0.71, while the reliability coefficients for the controllable perception and perception of different options subscales were 0.55 and 0.72, respectively. In this study, the internal consistency reliability of the total scale was found to be $\alpha = 0.84$.

The difficulty in emotion regulation scale (DERS) As a self-report tool, DERS was developed by Gratz and Roemer (2004) to assess difficulties in regulating emotional cues, experiences, actions, and verbal and/or nonverbal responses. The DERS measures six factors of ER difficulties: 1- Non-acceptance (non-acceptance of negative emotions) 2- Goals (difficulty engaging in goal-directed behaviors when experiencing negative emotions) 3- Impulse (impulse control difficulties), 4- Strategies (limited access to perceived effective ER strategies) 5- Awareness (lack of emotional awareness), and 6- Clarity (lack of emotional clarity). The Likert scale utilized in this study ranges from 1 (“rarely”) to 5 (“almost always”), as outlined by Gratz and Roemer (2004).

The Cronbach’s alpha of this tool was found to be 0.95 for all items and 0.84 to 0.93 for subscales (Lavender et al., 2017). In Iran, Moshirian Farahi et al. (2015) found that the overall internal consistency reliability of the DERS was 0.93, which means that the items on the scale are highly correlated with each other. The subscale reliabilities were also high, ranging from 0.85 to 0.88. This suggests that the DERS is a reliable measure of emotion regulation difficulties. The internal consistency reliability of the tool in this study was high, with an overall α coefficient of 0.85 for all items, and subscales demonstrating good reliability with a range of 0.72 to 0.88.

Procedure

The study was conducted with the necessary permits obtained and arrangements made with the management of the Metabolic Children Support Center. Families of the participants received food products without phenylalanine and related forms. Participants volunteered to take part in the MSC training program and did not receive any financial rewards for their involvement. After providing informed consent and being randomly assigned to either the Exp or Cont group, both groups completed questionnaires. The Exp group received MSC training for eight sessions, each lasting

150 min, once per week. The Cont group did not receive any educational intervention. Participants were reassessed at the end of the MSC program and three months after its completion. In accordance with research ethics, the Cont group was offered similar training sessions after the research was completed.

Protocol

The MSC training was conducted over 8 weeks, in a group-session format that took place in person, following the model developed by Germer and Neff (2019). Each session lasted for 2.5 h and focused on experiential learning through SC and reflective exercises, as outlined in the MSC curriculum (Neff & Germer, 2013). Participants were required to attend the weekly training sessions and complete assigned tasks, which typically involved practicing meditation exercises and informal activities learned in the sessions. A workbook published by the program developers contains examples of MSC exercises, and a detailed protocol for the program is also available (Germer & Neff, 2019).

The MSC program was performed in eight sessions. The first session provided an introduction to SC, and the second session focused on the practical application of mindfulness. The third session focused on the difference between reacting and responding when practicing mindfulness. The fourth session delved into the topic of SC, exploring it in-depth. In the fifth session, participants were taught the distinction between the concept of self-esteem and the concept of SC. The sixth session was dedicated to helping participants find their compassionate voice. In the seventh session, core values and compassionate strategies were taught to help participants manage difficult emotions. Lastly, in the eighth session, the program helped participants embrace their lives by practicing gratitude and self-appreciation.

Data analysis

The data collected were analyzed using repeated measures and mixed analysis of variance (ANOVA). ANOVAs were conducted to examine the potential differences in DIER between the Exp and Cont groups over time (pre-training, post-training, and follow-up). Finally, SPSS statistical software (version 24) was used to analyze the data.

Results

Table 1 displays the results of the frequency distribution, percentage, and chi-square test, which were utilized to compare the demographic characteristics of the groups under investigation.

The findings of Table 1 indicate that there is no statistically significant difference between the two groups being studied concerning the age of the mothers, their level of education, comorbid disorder, treatment status, and the developmental period of their child ($P < 0.05$). As a result, the groups are considered homogeneous concerning these characteristics.

Table 2 presents the descriptive statistics of the groups during the pre-training, post-training, and follow-up phases.

According to the results presented in Table 2, the mean scores of DIER and CF for the Exp group exhibited significant changes in the post-training, and follow-up phases when compared to the pre-training phase. While in the Cont group, no noticeable change was observed.

The Kolmogorov–Smirnov test results for the Exp group indicated that the data for both DIER ($Z = 0.25$, $p = 0.013$) and CF ($Z = 0.18$, $p = 0.200$) were normally distributed. Similarly, the Kolmogorov–Smirnov test results for the Cont group revealed that the data for DIER ($Z = 0.15$, $p = 0.200$) and CF ($Z = 0.11$, $p = 0.200$) were normally distributed.

Levene's test for the DIER ($F = 0.22$, $p = 0.882$) and CF ($F = 2.37$, $p = 0.135$) indicates the homogeneity of error variances in the two groups. The results of Mauchly's Test of Sphericity for the DIER ($W_{(\text{Mauchly's Test of Sphericity})} = 0.74$, Approx. Chi-Square $= 7.86$, $p = 0.020$), and CF ($W_{(\text{Mauchly's Test of Sphericity})} = 0.60$, Approx. Chi-Square $= 13.72$, $p = 0.001$), showed that the condition of equality of variance/covariance matrices and the assumption of sphericity is not met ($P > 0.05$); therefore Greenhouse–Geisser correction was used. The results of the Box's M Test for the variables of DIER (Box's $M = 18.92$, $p = 0.011$) and CF (Box's $M = 14.22$, $p = 0.051$) are not significant ($P > 0.05$).

Table 3 displays the results of the repeated measures analysis of variance conducted to examine both within-group and between-group effects of the dependent variables for the Exp and Cont groups.

The findings presented in Table 3 indicate that there is a significant between-group effect on CF ($P = 0.001$), DIER ($P = 0.0001$), and components of Goals ($P = 0.022$), Strategies ($P = 0.006$), Awareness ($P = 0.002$), and Clarity ($P = 0.044$) ($P < 0.05$). This result provides support for H1 and H2. However, the between-group effect on the components of Nonacceptance ($P = 0.325$) and Impulse ($P = 0.131$) is not significantly different between the two groups ($P > 0.05$), which partially supports H1.

Since the sample size was equal in the two study groups and the assumption of variance homogeneity was also valid. The results of the Bonferroni test indicated that the CF score in the Exp group was higher than the Cont group ($\Delta\bar{x} = 15.31$, $SE = 4.14$, $P = 0.001$) (Fig. 1). Also, the score of total DIER ($\Delta\bar{x} = -18.95$, $SE = 5.59$, $P = 0.002$), Goals ($\Delta\bar{x} = -3.40$, $SE = 1.32$, $P = 0.016$) (Fig. 2), Strategies

Table 1 Demographic characteristics of participants and their children with PKU

Variable		Group				Chi-Square
		Exp		Cont		
		N (%)		N (%)		
Characteristics of mothers						
Age	20–29	2	(13%)	6	(40%)	$\chi 2 = 17.92$ $P = 0.238$
	30–39	9	(60.3%)	7	(46.7%)	
	40–49	4	(26.7%)	2	(13.3%)	
Education	High school	5	(33.3%)	3	(20%)	$\chi^2 = 3.64$ $P = 0.301$
	Diploma and Post-Diploma	5	(33.3%)	9	(60%)	
	Undergraduate	3	(20%)	3	(20%)	
	Masters	2	(13.3%)	0	–	
Characteristics of children with PKU						
Comorbidity disorder	Mental retardation	5	(33.3%)	2	(13.3%)	$\chi^2 = 4.62$ $P = 0.461$
	Seizures	2	(13.3%)	1	(6.7%)	
	Aggression	1	(6.7%)	0	–	
	Hyperactivity	0	–	1	(6.7%)	
	Muscle weakness and paralysis	1	(6.7%)	1	(6.7%)	
	None	6	(40%)	10	(66.7%)	
Treatment status	Early treatment	8	(53.3%)	9	(60%)	$\chi^2 = 0.14$ $P = 0.713$
	Late treatment	7	(46.7%)	6	(40%)	
The developmental period of a child	0–2	6	(40%)	3	(20%)	$\chi^2 = 3.69$ $P = 0.303$
	3–6	4	(26.7%)	6	(40%)	
	7–11	2	(13.3%)	5	(33.3%)	
	12–18	3	(20%)	1	(6.7%)	

Table 2 Mean and standard deviation of DIER and CF in the mothers of PKU children in three measurement phases of the study

Component	Group	Pre-test		Post-test		Follow-up	
		M	SD	M	SD	M	SD
(DERS)							
DIER-36 total score	Exp	113.20	23.07	74.22	16.50	71.88	19.44
	Cont	107.07	21.13	101.73	13.49	107.27	12.85
Non-acceptance	Exp	18.66	5.79	10.27	3.49	11	4.68
	Cont	14.67	5.51	14.33	5.21	15.8	5.13
Goals	Exp	15.67	4.62	11.73	2.76	11	4.33
	Cont	16.07	5.06	15.8	4.09	16.73	4.17
Impulse	Exp	18.33	5.43	13.13	4.22	11.8	4.39
	Cont	17.6	5.55	16.07	5.01	17	4.34
Strategies	Exp	22.33	5.97	14.53	4.45	14.53	5.44
	Cont	23.07	8.13	21.93	5.87	22.93	5.28
Awareness	Exp	22.8	3.28	15.6	3.36	15.73	3.22
	Cont	22.4	4.07	21.8	4.8	21.73	4.08
Clarity	Exp	15.47	4.55	8.93	2.12	7.73	2.22
	Cont	13.27	3.61	11.80	3.82	13.07	2.99
(CFI)							
CF	Exp	77.46	22.96	107.06	11.34	109.73	12.08
	Cont	83.40	15.78	82.86	15.56	79.33	9.04

($\Delta\bar{x} = -5.51$, SE = 1.84, $P = 0.006$), Awareness ($\Delta\bar{x} = -3.93$, SE = 1.18, $P = 0.002$) and Clarity ($\Delta\bar{x} = -2$, SE = 0.95, $P = 0.044$) of the Exp group is lower than the Cont group. In other words, after MSC training, the scores of these dimensions decreased and showed a significant difference from the Cont group (It should be noted that the interaction effects

Table 3 Results of analysis of variance with repeated measures (within-group and between-group effects) on dependent variables of the experimental and control groups

Component		Source	F	P	(η^2)
(DERS)					
DIER-36 total score	between –group	G*	11.51	0.0001	0.29
	within-group	T*	32.18	0.0001	0.53
		T*G*	25.65	0.0001	0.48
Non-acceptance	between -group	G	1.02	0.325	0.03
	within-group	T	18.60	0.0001	0.39
		T*G	21.51	0.0001	0.43
Goals	between -group	G	6.64	0.022	0.19
	within-group	T	5.77	0.005	0.17
		T*G	7.66	0.001	0.21
Impulse	between -group	G	2.46	0.131	0.081
	within-group	T	15.96	0.0001	0.36
		T*G	8.91	0.0001	0.24
Strategies	between -group	G	8.95	0.006	0.24
	within-group	T	11.80	0.0001	0.30
		T*G	8.55	0.002	0.23
Awareness	between -group	G	11.13	0.002	0.28
	within-group	T	23.18	0.0001	0.45
		T*G	16.25	0.0001	0.37
Clarity	between -group	G	4.46	0.044	0.14
	within-group	T	24.49	0.0001	0.47
		T*G	17.08	0.0001	0.38
(CFI)					
CF	between -group	G	13.66	0.001	0.32
	within-group	T	16.90	0.0001	0.37
		T*G	22.71	0.0001	0.44

*G group, T Time

between time and group on dimensions of DIER can be seen in the supplementary material file).

Table 3 demonstrates that the repeated measures analysis of variance found significant main effects of time and interaction effects between time and group for CF and DIER, including their respective dimensions ($P > 0.001$).

In the following, since the main within-group (time) effect of the CF and DIER and its dimensions' score was significant, the Bonferroni post hoc test was used to compare the paired mean in the three stages of these variables in the Exp and Cont groups. The results showed that the scores of CF, Nonacceptance, and Awareness and Clarity were significantly different from the pre to post-training as well as the post-training to follow-up phases ($P < 0.001$). However, the scores of total DIER, Impulse, Goals, and Strategies Scores of the Exp group were not significantly different from the post-training to follow-up phases ($P > 0.05$). This indicated the stability of the effect of the intervention on these dimensions of DIER in the follow-up phases.

In the Cont group, scores of CF and all dimensions of DIER, there is no significant difference from pre to post-training as well as post-training to follow-up phases ($P > 0.05$).

The observed interaction between time and group was statistically significant for the variables of CF and DIER ($P > 0.001$). However, as illustrated in Figs. 1 and 2, the changes in the two groups were not uniform across the three stages of measurement. The CF scores for the Exp group increased from the pre- to the post-training, as well as from the post-training to the follow-up phases, while the scores for DIER and its dimensions declined across these three phases. These findings provide support for H1 and H2.

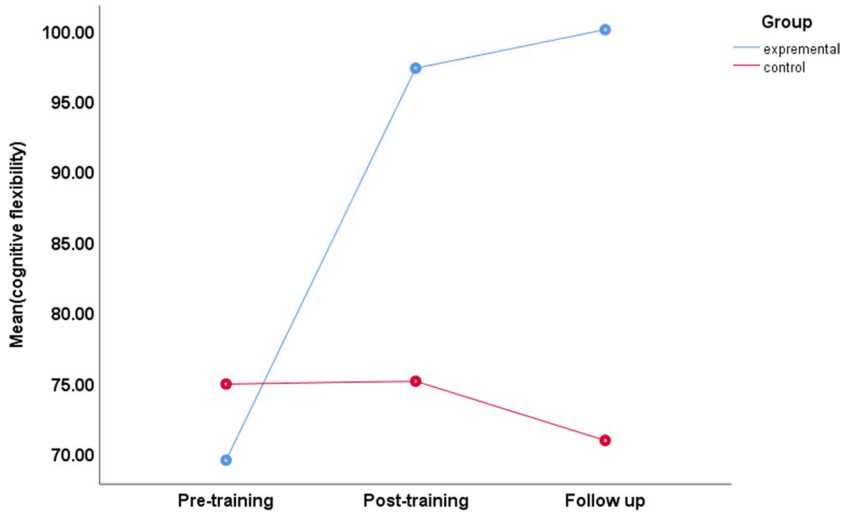

Fig. 1 Interaction effects between time and group on CF

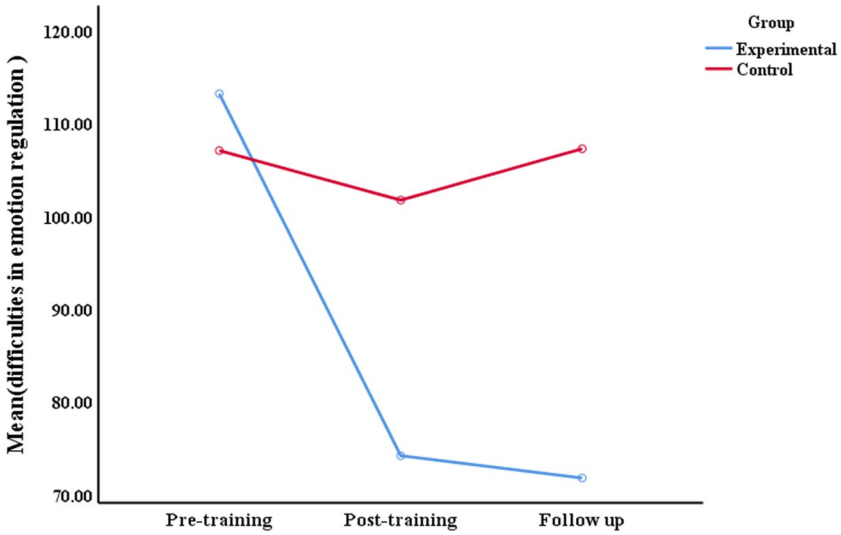

Fig. 2 Interaction effects between time and group on DIER

Discussion

The objective of this study was to explore the impact of MSC on DIER, its dimensions, and CF among mothers of children diagnosed with PKU.

MSC was found to significantly reduce DIER scores, as well as scores for Goals, Strategies, and Awareness in the Exp group compared to the Cont group ($p < 0.05$). Specifically, 29% of the reduction in the level of DIER among the subjects could be attributed to MSC training. These effects were sustained up until the follow-up stage. MSC training had no significant effect on the mother's Nonacceptance and Impulse scores ($P > 0.05$).

Inwood and Ferrari (2018) found that SC is a key factor in the way that emotion regulation (ER) affects mental health outcomes. SC provides a crucial framework for ER. Furthermore, Erol and Inozu (2023) found that people with lower levels of SC and distress tolerance were more likely to experience challenges in emotion regulation, such as difficulty recognizing, understanding, or accepting their emotions, difficulty using adaptive coping strategies, difficulty controlling their impulses, nonsuicidal self-injury when they are feeling distressed. The literature indicates that SC is inversely related to certain maladaptive ER strategies associated with psychological distress. These strategies include mental rumination, suppression of thought, and avoidance, as reported in some studies (Paucsik et al., 2023; Yela et al., 2020). SC may enhance parents' ability to respond to emotional distress and recover well-being (Shenaar-Golan et al., 2023).

In agreement with the findings of the present study, Gouveia et al. (2019) found that those with a stronger sense of mindfulness and SC skills tend to experience fewer difficulties with ER, which is linked with healthier eating behaviors. People who are more self-compassionate are better at regulating their emotions and have greater emotional clarity. They are also more receptive to difficult emotions and less likely to experience problems controlling impulsive behavior during stressful situations. Furthermore, they are more capable of accessing effective adaptive cognitive strategies of ER, such as cognitive reassessment, expression, acceptance, self-support, and tolerance, as reported in a study by Paucsik et al. (2023). Sources of mindfulness and SC help people work on their difficult emotions without avoiding, resisting them, or losing control (Williams et al., 2023; Yela et al., 2022). Finally, The effect size of the changes in DIER observed between the pre to post-training, and follow-up in this study is in agreement with previous research and theoretical explanations that suggest the negative link between SC and maladaptive ER.

Emotion labeling, awareness of emotions in the body, relief-relaxation, and acceptance are three effective strategies that MSC training uses to work with difficult emotions to facilitate awareness, processing, and acceptance of emotions that lead to inhibition of "corpus Amygdala" activity, which is responsible for activating the threat-defense system. Therefore, it triggers the brain's calming and nurturing system. The practice of MSC seems to promote efficient emotional responses by activating physiological systems related to self-healing and caring (Yela et al., 2022; Germer & Neff, 2019; Gilbert, 2017).

The research suggests that more self-compassionate people are more likely to face difficult emotions and thoughts resulting from challenging life situations instead of avoiding or ruminating on them (Yela et al., 2020). They possess more resources to reflect on and experience these emotions in the context of common humanity, with awareness and acceptance, and to conceptualize failure as a part of the human experience rather than a personal flaw (Neff, 2023). MSC can also help mothers to be more accepting of their limitations and imperfections, which can make it easier for them to let go

of negative thoughts and emotions. As a result, this mental capacity can help mothers to be more aware of their own and their children's emotions, which can lead to better self-regulation in the parent–child relationship. Mothers who are more self-regulated are less likely to act impulsively, less likely to be overly influenced by their children's emotions, and more likely to act by their parenting goals and values(Gouveia et al., 2016). Considering the significant correlation that exists between mothers' self-compassion, their parental feelings, and their child's external and internal problems (Cohen & Naaman, 2023), It seems SC can help mothers separate their responsibility for their child's illness from the negative emotions that they may experience as a result. Accepting failures and suffering as part of the human experience can help mothers develop a more resilient coping mechanism for dealing with difficult emotions such as sadness, loneliness, and shame (Gouveia et al., 2019).

The lack of a significant effect of MSC on the components of Nonacceptance and Impulse is in line with previous research such as Wisener and Khoury (2022) and Inwood and Ferrari (2018). The findings of these studies indicate that both the disposition for compassion and self-generated compassion are linked with less emotional impulsivity, reduced negative impact, more acceptance, and greater capacity to view events from other people's perspectives.

In explaining these results, it can be said that the MSC training focuses on the principle that to heal, one must face one's difficult emotions and stay in full contact with them. Neff and Germer (2013) count five steps to progress in accepting difficult emotions, and with each step, the person goes forward, and his resistance to emotions decreases. 1- Resistance stage 2- Exploration stage 3- Tolerance stage. 4- Allowing step 5- Friendship stage (Germer & Neff, 2019).

Due to the existence of different persistence among the participants and on the other hand, finding the skill in proper separation between multi-component, mixed, and similar emotions during the above steps, their non-judgmental acceptance may require more time. Also, mothers of PKU children after the diagnosis of the disease and at a younger age of their child, (e.g., from the time of diagnosis to before school age) due to grief caused by the diagnosis of their child's disease, the transmission of defective genes to the child and stigma caused by community labeling (social stigma) Tolerance of strangers' constant judgment, as well as the dependence of the child's growth and life on proper disease management by them, are more vulnerable groups(Carpenter et al., 2018). Because most of the participants in this study are mothers with newly diagnosed children with the disease up to 6 years old. Thus, they experience more negative emotions associated with feelings of grief (stigma), especially denial, anger, and depression before acceptance. These mothers may view PKU as a threat to their children, and this can disrupt the natural process of adjusting to accepting and coping with their difficult emotions.

One explanation for the lack of a significant reduction in Impulse-control difficulties in mothers of PKU children following the MSC training may be related to a classification effect. The mean scores of the Impulse component in the pre-training stage were low (as shown in Table 2), with most scores falling in the 0 to 10% and 11 to 35% categories. It is possible that most participants exhibited impulsive behavior at lower levels before the intervention, making it challenging to reduce the same amount to lower levels.

Furthermore, The results of the study showed that MSC training helped to increase the CF of mothers in the Exp group. The intervention accounted for 32% of the changes in CF scores. This finding is in agreement with other studies, which have shown that SC can affect both physiological and behavioral indicators of stress, as well as psychological and physiological flexibility(Svendsen, 2019), also found a positive relationship between SC and CF, adaptability, and psychological well-being (Pyszkowska & Rönnlund, 2021). On the other hand, the study by Kılıç et al. (2022) showed that there was a negative and significant correlation between SC and psychological inflexibility, and both of them had a high correlation with psychological distress.

Mothers with PKU children often experience intense and frequent negative emotions, like mental stress and depression, which can negatively affect their CF (Fidika et al., 2013). CF requires the ability to be present at the moment, differentiate oneself from inner thoughts and experiences, and communicate effectively. MSC emphasizes inner experiences and mindfulness processes to develop non-judgmental acceptance of life problems as part of human commonality, which can facilitate warmth and compassion for oneself and others instead of harsh self-judgment (Germer & Neff, 2019). Such a view enables these mothers to develop more flexibility and change their cognitive attitude toward the challenges they face, leading to a sense of controllability of the situation and better adaptation. Conversely, not being aware of unpleasant thoughts and feelings can result in drowning in these experiences, leading to an inability to accept painful experiences, low capacity for flexibility, lack of controllability of the condition, and inability to adapt to it (Pyszkowska & Rönnlund, 2021).

MSC training helps mothers with PKU children practice CF and its separate processes, such as achieving compassion toward oneself and others, increasing mindfulness, dealing with thoughts and feelings instead of controlling them, cognitive dissonance, and experiential avoidance. By paying attention to the present moment without judgment, people can change their relationship with their emotions, thoughts, and other internal experiences, facilitating flexibility and adaptability in emotional responses to various situations. MSC teaches different ways to regulate emotions

in everyday situations, leading to the development of newer choices through expressing or solving emotional difficulties available to the individual in critical situations.

SC is a constructive way to approach distressing thoughts and feelings. SC can be seen as a way of coping with stress that allows people to respond more adaptively to difficult situations and to see them in a more positive light (Neff, 2023; Shenaar-Golan et al., 2023). This alternative and flexible attitude helps individuals use more adaptive and logical responses rather than maladaptive strategies to deal with negative emotions (Paucsik et al., 2023). Mothers are advised to employ alternative explanations, positively reframe their thoughts, embrace challenging situations or stressful events, and divert their energy from controlling emotions or over-synchronizing with internal states and responding automatically or impulsively to valuable actions. They are also encouraged to respond to situations according to their values, goals, and needs despite the existing problems related to caring for a child (Lennard et al., 2021).

Conclusion

Overall, the findings suggest that MSC skills can help mothers of PKU children develop a more flexible cognitive attitude and a positive outlook. These skills can also reduce the distress caused by challenges, negative parenting experiences, and maladaptive social comparisons with parents of healthy children. Furthermore, participating in a group-based educational intervention may provide mothers with a platform to share their feelings and receive support. SC and mindfulness can serve as protective factors and provide mothers with more emotional resources to cope with difficult living conditions. The findings of this study highlight the need for SC and mindfulness-based treatment methods for mothers of PKU children.

Limitations

The findings of this study should be interpreted with caution, as there are several limitations to consider. First, the sample consisted mainly of mothers with PKU children, and the absence of fathers and mothers of each patient may have limited the ability to make more comprehensive comparisons. Additionally, The number of participants was relatively small. The study was carried out exclusively on mothers who received support services and special dietary products for PKU patients from the Metabolic Patients Support Institute. It is possible that the mental health outcomes of the study participants differed from those of the overall population of families and individuals who lack access to support services and dietary products, due to these factors. Due to the limited sample, some personality variables that could have interfered with the results (e.g., trait anxiety and state anxiety, etc.) were not controlled. The findings of this study should be interpreted with caution, as they may not be generalizable to larger populations.

Suggestions and future studies

Future studies are recommended to investigate MSC's impact on other psychological flexibility components. Further research is needed to explore the close association between MSC and specific kinds of difficulties in ER, such as whether SC operates through negative emotion tolerance when a person has reduced SC, or through high-order ER strategies like cognitive reappraisal when the person has a strong sense of SC. Additionally, as there are intercultural differences in the definition of components like anger, shame, incompetence, self-blame, and doubts, there is a need to conduct more research to investigate the effect of MSC training in the context of Eastern culture and subcultures, which differ from Western culture in nature. Including mothers of healthy children for comparison might have provided a more comprehensive understanding, and to identify the factors that may have influenced the effectiveness of the intervention.

Parents of PKU children often feel isolated and have few chances to connect with other parents with similar conditions, which can make it difficult for them to share their worries and distress. Therefore, there is a need to establish educational-supportive groups for parents, such as MSC training, along with other nutritional and therapeutic services. Education based on SC and mindfulness can provide families with effective coping strategies to accept PKU and its emotional challenges in different stages of the child's development.

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Authors' contributions N. H. collected all data; formal analysis; investigation; methodology; writing –review and editing. J. R.Y., and S.B. Conceptualized, supervised, initial review, writing – original draft preparation, interpreted data. A.H.V. Conceptualized; analyzed, and interpreted all data, supervised the whole study, and was actively involved in addressing the feedback provided by both the editor and the reviewers, and M.N. Conceptualized; analyzed, and interpreted all data and supervised the whole study. All authors received and approved the final form of the manuscript.

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Declarations

Ethical standards The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008.

The present study was approved by the institutional review board of the Mohaghegh Ardabili University with code No: IR.UMA.REC.1400.013.

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Conflict of interests The authors declare that they have no conflict of interest. All authors declare to have no financial or personal relationships that could inappropriately influence the research described.

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