



Impact of mindfulness versus supportive sex education on stress in women with sexual interest/arousal disorder

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Abstract

Low desire in women is the most common sexual difficulty, and stress has been identified as a significant predictor of symptoms. We evaluated a mindfulness-based cognitive therapy (MBCT) group treatment versus a sex education comparison group treatment (STEP) on self-reported stress and on the physiological stress response measured via morning-to-evening cortisol slope in 148 women with a diagnosis of sexual interest/arousal disorder (SIAD). Perceived stress decreased following treatment in both groups, and significantly more after MBCT. The cortisol slope was steeper (indicative of better stress system regulation) from pre-treatment to 6-month follow-up, with no differences between the groups. As an exploratory analysis, we found that the reduction in perceived stress predicted increases in sexual desire and decreases in sex-related distress for participants after MBCT only. These findings suggest that group mindfulness targeting women with low sexual desire leads to improvements in self-reported and physiological stress, with improvements in self-reported stress partially accounting for improvements in sexual desire and distress.

Keywords Mindfulness · Sex education · Stress · Low desire · Sexual interest/arousal disorder · Cortisol

Sexual dysfunction in women

Nearly one in three women across the life span report experiencing sexual difficulties (Nappi et al., 2016). The most prevalent sexual symptom for women is low sexual desire or lack of interest in sex, with 34.2% of women in the United Kingdom reporting this issue lasting 3 months or more in the past year (Mitchell et al., 2013). Female Sexual Interest/Arousal Disorder (SIAD) is defined by the Diagnostic and Statistical Manual of Mental Disorders (5th

edition; American Psychiatric Association, 2013) as a disorder characterized by at least three of the following: reduced or absent (1) interest in sexual activity (2) erotic thoughts or fantasies (3) initiation of sexual activity (4) sexual excitement/pleasure (5) sexual interest or arousal in response to any internal or external sexual cues and (6) genital or non-genital sensations. To be diagnosed, the defining symptoms must elicit significant distress and persist for a minimum of six months (5th ed.; DSM–5; American Psychiatric Association, 2013).

Among the various studied contributors to SIAD (Brotto et al., 2016), stress has been identified as a significant risk factor that is commonly associated with lower sexual functioning due to the body prioritizing and allocating resources to survival over non-vital bodily functions (Hamilton & Meston, 2013). Chronic life stress and increased stress responsiveness are associated with reduced levels of sexual desire in individuals (Basson et al., 2019; Hamilton & Julian, 2014) as well as couples (Traeen et al., 2007), and also seen in women with hypoactive sexual desire disorder (the former DSM-IV-TR diagnosis for low desire) compared to women without sexual desire concerns (Basson et al., 2019). The link between stress and sexual response

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is further reinforced by studies showing that genital sexual arousal in response to sexual stimuli is significantly lower in women suffering from chronic stress (Hamilton & Meston, 2013). Moreover, those experiencing acute stress not only had lower levels of genital arousal but also lower subjective sexual arousal and sexual desire in response to erotic stimuli (ter Kuile et al., 2007). Stress can not only directly impact sexual desire and arousal, but can also negatively impact key factors in forming and maintaining healthy and pleasurable sexual experiences, such as relationship quality (Bodenmann et al., 2006; Harper et al., 2000; Neff & Broady, 2011). Daily stress is significantly correlated with lower marital quality and decreased relationship functioning. Additionally, stress is correlated with both emotional and cognitive changes that result in high distractibility—a key predictor of sexual dysfunction (Hamilton & Meston, 2013). Rather than focusing on sexual cues, women with high stress may fixate on their stressors, ultimately reducing the attention to sexual response and contributing to sexual dysfunction (Nobre, 2009). Since stress plays a significant role in disrupting sexual response and desire in women, it is reasonable to speculate that treatments which directly address stress may have a beneficial impact on sexual response.

Measuring stress response

The ability to respond appropriately to stress is an important basic adaptive mechanism, and activation of the hypothalamic-pituitary-adrenal (HPA) axis is a central component of this response (Herman et al., 2016). The hypothalamus receives nerve fibers from a number of brain areas including the limbic system such that HPA activation is modulated by a wide range of psychological and physiological stimuli or stressors, and involves an interaction among the hypothalamus, pituitary, and adrenal glands, ultimately resulting in the secretion of cortisol—the major glucocorticoid hormone in humans. In the short term, HPA activation enables the individual to respond to or cope with acute stressors. However, increased or chronic exposure to stressors can lead to HPA dysregulation, with abnormal basal and stress levels of HPA hormones and adverse behavioral and physiological consequences that can compromise health and possibly even survival (McEwen, 1998). Chronic hyperactivity of the stress response system is seen in major depressive disorder (Lok et al., 2012) whereas hyporeactivity is observed in post-traumatic stress disorder (Rohleder et al., 2004) and, of relevance to the current study, in hypoactive sexual desire disorder (Basson et al., 2019).

An important marker of HPA axis dysregulation is a disruption in the diurnal pattern of secretion of HPA hormones.

The most common measures of diurnal HPA activity are the cortisol awakening response (CAR), an increase of cortisol levels during the first 30 min after awakening, and the diurnal cortisol slope (i.e., the difference in cortisol levels from morning to evening). A flattened diurnal cortisol slope, indicative of HPA axis dysregulation, has been shown to be associated with poorer mental and physical health (Adam et al., 2017), and importantly, has been observed among women with hypoactive sexual desire disorder compared to a control group without sexual desire concerns (Basson et al., 2019).

Stress, sex, and mindfulness

Given the established role of stress in impacting sexual desire, treatments that directly address stress would be expected to also have a beneficial effect on sexual desire. Mindfulness is one such tool that has a positive impact on stress (Grossman et al., 2004). Practically, mindfulness entails moving the focus of attention from negative thoughts about the past or future, and shifting it toward a neutral, non-judgmental attitude and observation of one's experience of the present moment, whether that be toward one's thoughts, body sensations or sensory experience (Brown & Ryan, 2003). Mindfulness is an equanimity-based approach that allows a person to turn toward even unpleasant or challenging aspects of their inner experience with curiosity and non-judgement. Mindfulness-based stress reduction has been used in a wide variety of populations struggling with chronic stress (Grossman et al., 2004; Rice et al., 2019) and has been shown to directly impact the regulation and habituation of HPA axis activation (Aguilar-Raab et al., 2021; Ho et al., 2020). For example, mindfulness training leads to a robust diurnal rhythm — i.e., a steeper slope in cortisol — indicative of a more regulated HPA axis (Schonert-Reichl et al., 2015).

Studies conducted over the past 15 years have examined mindfulness as a treatment for SIAD in women and demonstrated positive effects including increased desire for, engagement in, and arousal toward sexual activity (Brotto & Basson, 2014; Brotto et al., 2021; Lin et al., 2019; Rashedi et al., 2022). These studies have delivered mindfulness in both individual and group format, and experimented with 3, 4, and 8 session formats. In one of the few large randomized clinical trials of mindfulness versus supportive sex education to women with SIAD, an 8-week mindfulness intervention invited participants to practice mindfulness exercises formally in the first few sessions, and then progressively integrated mindfulness practice in more sexual contexts such as while looking at oneself in a mirror, engaging in self-touch, non-sexual touching with a partner (e.g., sensate

focus), and eventually during sex with a partner (Brotto et al., 2021). Immediately after treatment, the mindfulness group saw significant improvements in sexual desire, sexual distress, relationship satisfaction, and rumination, and these improvements were retained at both the 6-month and 12-month follow-up time points (Brotto et al., 2021). They also reported a significant improvement to their quality of life and a general satisfaction with the treatment and the improvements they saw. The supportive-expressive sex education group did not see the magnitude of improvements in sexual distress, relationship satisfaction, or rumination that was seen in the mindfulness group.

Considering that evidence supports Mindfulness-Based Cognitive Therapy (MBCT)'s role in regulating stress both psychologically (as assessed by self-report measures) and physiologically (as assessed by HPA activity and cortisol slope) (Aguilar-Raab et al., 2021; Ho et al., 2020), the aim of the present study was to examine if MBCT is effective at improving stress outcomes for women with SIAD. We used an MBCT intervention that adapted the second edition MBCT treatment protocol (Segal et al., 2013) to be suitable for women seeking treatment for sexual concerns. Meditation instructions were modified to optimize skill development, with a focus on training equanimity, interoceptive awareness, and metacognitive awareness. The definition of equanimity used in this study for skill-training purposes was 'bringing an equal interest to pleasant, unpleasant and neutral sensations, without reactivity or identification' (Grabovac et al., 2011). Two outcomes of stress were included in the present study: (1) a self-report measure of stress using the Perceived Stress Scale; and (2) a physiological measure of stress using the diurnal cortisol slope. A comparison group received treatment utilizing Supportive Sex Education and Therapy (STEP) (Brotto et al., 2021). We hypothesized that those randomized to the MBCT group would show greater improvements in self-reported stress, and a steeper cortisol slope than those randomized to STEP from pre- to post-treatment. As an exploratory outcome, we also examined the association between improvements in perceived stress and improvements in self-reported sexual desire as well as improvements in sex-related distress.

Materials and methods

Participants

Data from this study were taken from a published randomized clinical trial (Brotto et al., 2021). A total of 148 women who self-reported symptoms of low or absent sexual desire were the focus of recruitment. They were required to meet the following inclusion criteria: (1) symptoms consistent

with SIAD, which was formally assessed in a face-to-face interview by trained study personnel; (2) symptoms lasting for at least 6 months and being associated with personal distress; (3) a willingness to attend eight weekly group sessions; (4) 19 years of age or older; (5) fluent in English; and (6) a commitment to not begin any new treatments for low desire for the duration of the study period. Exclusion criteria were: (1) having an untreated psychiatric or medical condition that interfered with group attendance; (2) self-reported vulvar pain; and (3) symptoms of significant dissociation that might interfere with their participation in mindfulness exercises (Kuyken et al., 2012).

Procedure

Participants first responded to advertisements (asking for women distressed by low sexual desire who may be interested in participating in a research study evaluating treatment) by email, and were subsequently scheduled for a telephone screening by a trained research assistant who explained the study procedures and assessed entry criteria. The assistant also obtained informed consent and booked an in-person interview that had the goal of assessing and confirming the SIAD diagnosis, asking about history of sexual assault, and determining fit for group by one of the group facilitators. Sexual assault history was not part of the inclusion criteria, but was information provided to the group facilitators to assist in delivering trauma-informed care. At the end of the interview, participants were provided with a saliva sampling kit and detailed written and verbal instructions on how to collect their samples at home. The kit included two sets of daily sampling tubes, a specimen collection straw, a labeled zip loc freezer storage bag, instructions, a check-list, and a log sheet (which asked about date of last menstrual cycle, exact times that the sample was taken and when the person woke up and last ate, and places that they could document their alcohol, prescription medication, caffeine, nicotine, and other consumption). They were also given a link to a YouTube video that our research team created to instruct how to collect the saliva sample. They were asked to collect saliva samples on two typical days that did not need to be consecutive, and to avoid collecting saliva while menstruating. The saliva collection instructions also indicated that participants should avoid eating, drinking, chewing gum, smoking, flossing, consuming alcohol, brushing their teeth, or using mouthwash for at least 30 min prior to sample collection. Written instructions also directed them to rinse their mouths with water at least 30 min prior to sampling. The morning sample was to be collected between 25 and 40 min after waking and the evening sample was to be collected 30 min prior to going to sleep. Following collection of saliva, participants were directed to store the vials

in their home freezer no later than 30 min after collection. Spare tubes were provided in the event that both morning and evening samples were not collected on the same day. In such cases, the single sample was discarded. Participants were then asked to return their saliva samples to the research assistant at the research site when they returned to take part in an in-lab sexual arousal assessment (data from the sexual arousal assessment are reported in Chivers et al., 2024). Collection of these saliva samples at baseline/pre-treatment comprised t1 of the study timeline. Following this, the research assistant emailed the participants a link to an online questionnaire battery (see [Measures](#) section below), and following that, they were randomized to either MBCT or STEP.

At 2–4 weeks after the final treatment session (t2), and at 6- and 12- month follow-up (t3 and t4), participants were given identical saliva kits and asked to follow the same procedures as they did at pre-treatment (t1). They returned their saliva samples to the research assistant at the time of their next in-person sexual arousal assessment. The study was approved by both the University of British Columbia Clinical Research Ethics Board (H12-01659) and the associated Vancouver Coastal Health Research Institute Hospital Research Ethics Board. The study and hypotheses were pre-registered at ClinicalTrials.gov NCT01690897.

Measures

Demographic Variables. Questions focused on demographic characteristics, e.g., age, ethnicity, education, sexual orientation, relationship status and duration. Questions about past treatments sought for their desire concerns were also completed. Questions were asked with a mixture of free response (e.g., age) and fixed choice response options.

Perceived Stress. We used the 10-item Perceived Stress Scale (PSS-10; Cohen et al., 1983) designed to measure the degree to which situations in one's life are appraised as stressful. In an analysis of three large national surveys, Cohen and Janicki-Deverts (2012) found internal reliabilities for the PSS-10 ranging from $\alpha=0.78$ to 0.91. In this sample, Cronbach's alpha at t1, 2, 3, and 4 ranged from 0.87 to 0.91.

Trait Anxiety. We used the State-Trait Anxiety Inventory (STAI), Trait subscale (20 items) at pre-treatment only to examine it as a predictor of change in cortisol following treatment. The STAI-T has excellent test-retest coefficients (average $r=.88$ at a variety of time intervals; Barnes et al., 2002). In this sample, Cronbach's alpha at t1, 2, 3, and 4 ranged from 0.91 to 0.94.

Sexual Desire. The moderating effect of changes in stress on sexual desire was analyzed as an exploratory outcome and was measured using the 14-item Sexual Interest/Desire

Inventory (SIDI; Clayton et al., 2006), which produces a comprehensive measure of sexual desire, interest, and arousal. Total scores range from 0 to 51, with higher scores indicating greater sexual desire and response. The measure has excellent internal consistency (Cronbach's $\alpha=0.90$), and excellent concurrent validity, correctly identifying 94.7% of women with hypoactive sexual desire disorder using a cut-off score of 33 (Clayton et al., 2010). In this sample, Cronbach's alpha at t1, 2, 3, and 4 ranged from 0.81 to 0.87.

Sex-Related Distress. The moderating effect of changes in stress on improvements in sex-related distress was also part of an exploratory analysis. This was measured with the 13-item Female Sexual Distress Scale – Revised (FSDS-R; Derogatis et al., 2008). Total scores range from 0 to 52, with higher scores indicating greater distress. The FSDS-R has been found to have excellent concurrent validity, correctly identifying 92.7% of women with clinically significant low desire (Derogatis et al., 2008). In this sample, Cronbach's alpha at t1, 2, 3, and 4 ranged from 0.92 to 0.96.

Cortisol Slope. The diurnal cortisol slope is the difference in cortisol levels from morning to evening (Adam & Kumari, 2009). To assay salivary cortisol concentrations, samples were vortexed and centrifuged at 1,400 g for 10 min at 18 °C. Salivary cortisol was measured using the commercially available High Sensitivity Salivary Cortisol Enzyme Immunoassay Kit (Salimetrics Assays, 1-3002, State College, PA) according to the standard protocol. The minimum amount of saliva required by this assay is 25 μ l, and intra- and inter-assay coefficients of variation were 4.6% and 6.0%, respectively.

Treatments

Both arms (MBCT and STEP) were delivered over eight weekly sessions, 2.25 h in length, by sexual health clinicians who had additional training in mindfulness-based therapy and had their own personal mindfulness practices (Crane et al., 2010). Details of the interventions are provided in the original randomized clinical trial publication (Brotto et al., 2021). There were two facilitators per group, and each group had between 3 and 10 participants with 88% of groups including 5–9 participants. Twelve MBCT and 13 STEP groups were formed and went through treatment. None of the facilitators led an MBCT and a STEP group at the same time, in order to adhere to the theoretical orientation of the group they were running.

Mindfulness-based Cognitive Therapy (MBCT): The MBCT intervention focused on in-session practice of a variety of mindfulness exercises, ranging from an eating meditation, body scan, breath awareness practice, mindfulness of thoughts, mindful movement, to eliciting a difficulty

meditation. Several mindfulness practices were paired with having participants touch their own body, or following the use of a sexual aid like a vibrator, fantasy, or erotica (at home). Each of the eight sessions also contained psychoeducational information about sexual desire and response, and this material was identical in the STEP treatment. Following each session, participants were emailed a link to guided mindfulness practices that they could download and listen to between sessions (they were asked to practice mindfulness, as best as they could, for five days per week). In addition to tracking the frequency of their mindfulness practices, they were also provided with a log to record their observations during the mindfulness exercises.

Supportive Sex Education and Therapy (STEP): As noted, the educational information in STEP was identical to that in the MBCT arm, except that it was delivered using the principles of supportive-expressive therapy (Leichsenring & Leibing, 2007), which means that group participants were encouraged to interact with and validate one another. Topics included: education about the sexual response cycle, prevalence of sexual concerns, the causes and perpetuating factors of low desire, the basic principles of CBT, and sensate focus, which was introduced in the last week, and which involved some minimal information on interoceptive awareness through its instructions to participants to pay attention to their body sensations while being touched by a partner. The number of sessions and the length of each session in STEP was identical to the MBCT arm but STEP had additional time for question and answers, and for having participants validate and support one another.

In both groups, the last session focused on the importance of sustaining the practice of any skills learned in an ongoing basis; however, there were no additional “booster” sessions or contact with the group facilitators.

Data analysis plan

Cortisol slopes were calculated using multilevel analysis with random intercept in which two time points of the daily saliva collection were used as a predictor. The time was coded from evening to morning to create slopes with positive values in order to facilitate the interpretation of the main analyses. One extreme outlier’s cortisol scores (cortisol values > 5 standard deviations above the mean) were removed from the analysis and the remaining slopes were all positive, indicating a drop in cortisol from the morning peak to the evening collection point. The final slope value was averaged across the two days of saliva collection. Initial multi-level mixed modeling [MLM] analyses included day of collection as another random effect but it did not explain any substantial amount of

residual variance and therefore it was dropped from the model.

The study was adequately powered for the main outcome analysis and the details are described in the original publication (Brotto et al., 2021). The impact of treatment on cortisol slopes and self-reported stress was analyzed using a multilevel mixed model with random intercepts which included main effects of time (within-participant four measurement points - pretreatment, post-treatment, 6-month, and 12-month follow-up) and the between-participant factor comparing two treatments (STEP versus MBCT), as well as the interaction of these two factors (changes from pretreatment to post-treatment time points were compared between the two groups).

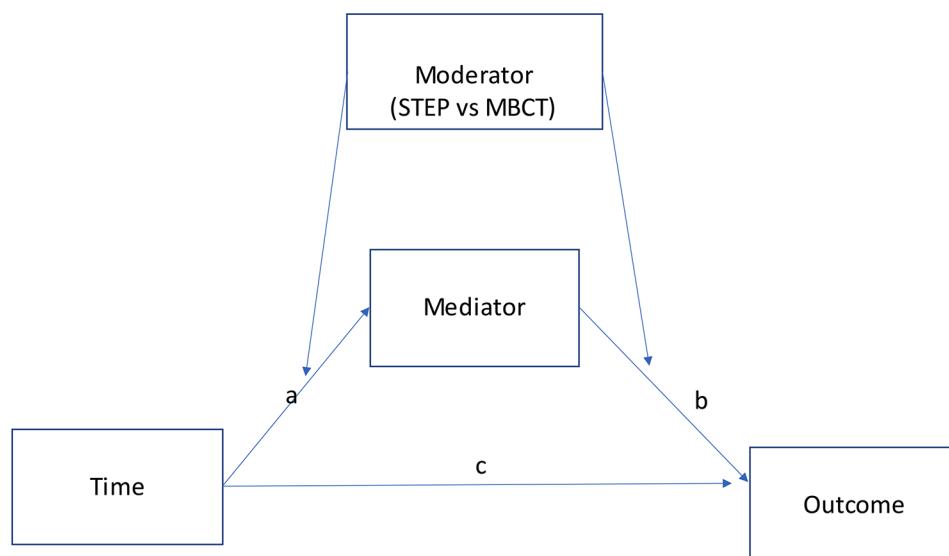
Baseline data were missing for 10 participants for cortisol and for 27 participants for PSS-10 scores. The higher number of missing data on the PSS-10 was due to the measure being introduced after some participants had already filled out the baseline questionnaire. The participants with missing PSS-10 and cortisol baseline data were compared on all demographics to those who had complete data, and there were no significant differences on any personal characteristics, all p 's > 0.05.

We next conducted moderated mediation analyses to test an exploratory directional hypothesis that improvement in perceived stress scores mediated the impact of treatment on the improvements in two main sexual functioning outcomes of the study: sexual desire (as measured by the SIDI) and sex-related distress (as measured by the FSDS-R), and whether such mediation was conditional on the type of treatment (STEP versus MBCT). We used a moderated mediation model (see Fig. 1) described as Model 5 in Preacher et al. (2007) and presented in Fig. 10.1 panel C in Hayes (2013). Mediation effect was tested for changes between two time points: pre-treatment (t1) and 12-month follow-up (t4).

Following the recommendations of Zhang et al. (2009) on testing mediation in multilevel models, the approach of mediator being centered within context with reintroduction of the subtracted mean (CWC(M) was used by entering person centered mediator variable and person mean as predictors in each model (Wang & Maxwell, 2015). Thus, each person’s average across four time points (person intercept) was included as well as the difference scores between each time assessment and the person average (within person change). This approach allows for examining association of change in mediator with the change in outcome.

The moderated mediation was tested by first fitting a model for moderated path a in which the change in the mediator was regressed on time, type of treatment (STEP versus MBCT), and their interaction. A significant

Fig. 1 Model illustrating treatment type (STEP versus MBCT) as a moderator of the pathways from treatment to improvements in sexual desire and sex-related distress mediated by perceived stress



interaction term would indicate that the impact of treatment on changes in the mediator was conditional on the type of treatment. Next, a model for moderated path b was fitted in which changes in the outcome were regressed on time, type of treatment (STEP versus MBCT), mediator and the interaction of type of treatment and mediator. A significant interaction term would indicate that the impact of the changes in the mediator on the changes in the outcome was conditional on the type of treatment. Finally, the conditional indirect effect was computed by multiplying path a and path b unstandardized coefficients separately for STEP and MBCT arms. The significance of those indirect effects was estimated using the bootstrap method (Hayes, 2013; MacKinnon et al., 2002). In this approach, the indirect effect is computed as the product of path a and path b unstandardized coefficients and the 95% confidence interval for the values of this effect is established. It is assumed that the indirect effect is statistically significant if the 95% CI does not include zero (Preacher et al., 2007). Statistically significant indirect effects indicate the presence of mediation. In our case of moderated mediation, the bootstrap analysis was performed separately for STEP and MBCT participants.

Results

Participants

As reported on in Brotto et al. (2021), participants in the MBCT ($n = 70$) and STEP ($n = 78$) arms did not differ on any demographic characteristics except that those randomized to STEP were significantly more likely

to be using hormonal therapy and to be self-employed (Table 1).

Effects of treatment on self-reported perceived stress

Means and standard deviations for perceived stress are reported in Table 2 by treatment arm and time of assessment. Results for multilevel mixed model analyses, including effect sizes and confidence intervals, are reported in Table 3.

PSS-10 total scores showed significant improvements (scores decreased) from t1 to all three posttreatment time points with small effect sizes (d 's ranged from 0.21 to 0.26). These effects reflect the main treatment effect averaged across both treatment arms and are qualified by a significant interaction. The interaction effect of time and treatment for the t1- t4 comparison was nearly medium in size ($d = 0.41$) and statistically significant, revealing that MBCT led to over a 2.5-point greater reduction in perceived stress between pre-treatment (t1) and 12-month follow-up (t4) as compared to STEP. Thus, the effect size of perceived stress reduction t1 to t4 in the MBCT arm was of medium size ($d = 0.60$).

Effects of treatment on cortisol slopes

The cortisol slope increased (became steeper) between pretreatment (t1) and 6-month follow-up (t3) indicating a greater difference between morning and evening levels of salivary cortisol at t3 as compared to t1 ($d = 0.40$, a moderate effect size; Fig. 2). However, there was no significant time by group interaction ($d_s < 0.14$) indicating that the changes in slope were not significantly different between

Table 1 Baseline characteristics of participants in the sex education (STEP) and mindfulness-based cognitive therapy (MBCT) treatment arms

Measure	STEP	MBCT	Total
Number of Participants	78	70	148
Age (years), mean \pm SD	37.9 \pm 12.2	39.3 \pm 13.2	38.6 \pm 12.6
Relationship status, n (%)			
Common-law	22 (28.6)	20 (29.4)	42 (29.0)
Dating	11 (14.3)	9 (13.2)	20 (13.8)
Married	30 (39.0)	31 (45.6)	61 (42.1)
Single	14 (18.2)	8 (11.8)	22 (15.2)
Length of current relationship (years), mean \pm SD	11.9 \pm 10.5	10.8 \pm 10.1	11.4 \pm 10.3
Satisfaction with relationship closeness, n (%)			
Yes	34 (45.9)	29 (43.3)	63 (44.7)
No	40 (54.1)	38 (56.7)	78 (55.3)
Ethnicity, n (%)			
East Asian	7 (9.1)	3 (4.3)	10 (6.8)
Euro-Canadian	60 (77.9)	57 (82.6)	117 (80.1)
Latin American	1 (1.3)	0 (0.0)	1 (0.7)
Middle Eastern	1 (1.3)	2 (2.9)	3 (2.1)
South Asian	2 (2.6)	4 (5.8)	6 (4.1)
Other	6 (7.8)	3 (4.3)	9 (6.2)
Sexual orientation, n (%)			
Bisexual	11 (14.1)	10 (14.5)	21 (14.3)
Heterosexual	62 (79.5)	52 (75.4)	114 (77.6)
Lesbian	3 (3.8)	4 (5.8)	7 (4.8)
Other	2 (2.6)	3 (4.3)	5 (3.4)
Education, n (%)			
High school	5 (6.5)	1 (1.4)	6 (4.1)
College/technical or trades	17 (22.1)	15 (21.7)	32 (21.9)
Undergraduate degree	35 (45.5)	28 (40.6)	63 (43.2)
Master's degree	15 (19.5)	23 (33.3)	38 (26.0)
Doctorate or MD	5 (6.5)	2 (2.9)	7 (4.8)
Significant medical history, ¹ n (%)	27 (35.1)	27 (39.1)	54 (37.0)
Currently receiving hormone therapy, n (%)	13 (16.7)	4 (5.8)	17 (11.6)
Number of years with current sexual concerns, mean \pm SD	9.1 \pm 7.8	8.7 \pm 8.0	8.9 \pm 7.9
Report a history of sexual assault, n (%) ²	25 (32.1)	29 (42.0)	54 (36.7)
As an adult	17 (21.8)	20 (29.0)	37 (25.2)
As a child			
Received past treatments for low desire, n (%)	19 (24.4)	11 (16.2)	30 (20.5)

¹Reported medical conditions listed from most to least endorsed: inflammatory bowel disease (e.g., Crohn's, colitis), cancer, endometriosis, hypothyroidism, asthma, benign tumor/growths (e.g., fibroids, cysts), diabetes, genital herpes, celiac disease, high blood pressure, migraines, osteoarthritis, seizures, cervical dysplasia, chronic fatigue syndrome, fibromyalgia, heart condition, kyphosis, iron deficiency, Meniere's disease, monoclonal B cell lymphocytosis, multiple sclerosis, neutropenia, osteoporosis, sciatica, significant physical injuries, typhoid fever

²A total of $n = 12$ individuals reported a history of sexual assault as an adult and as a child

Table 2 Mean levels for Perceived Stress and Cortisol Slope by Time of Assessment (t1, t2, t3, t4) and treatment arm (sex education; STEP and mindfulness-based cognitive therapy; MBCT)

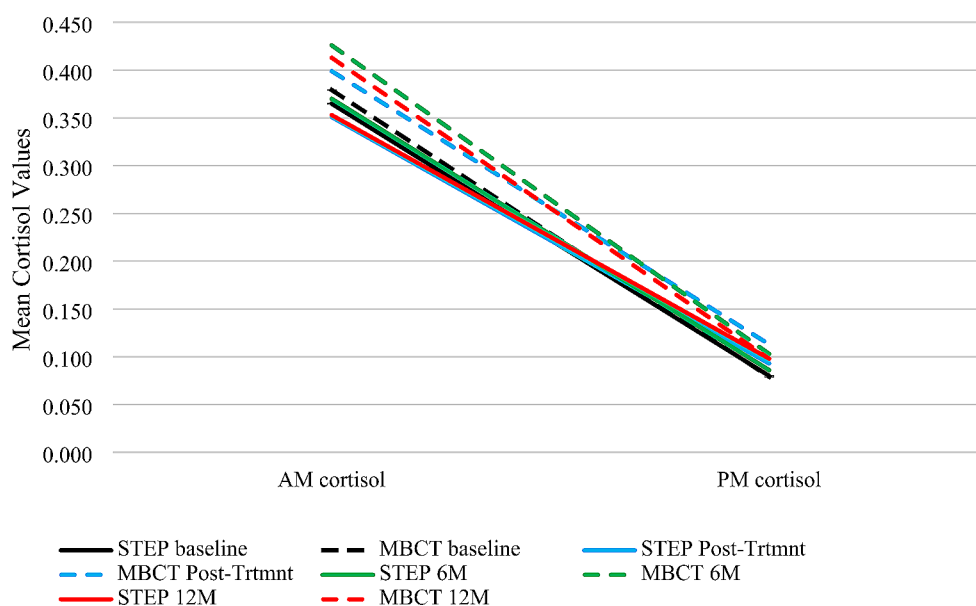
Variable and Group	Baseline/Pre-treatment (t1) M (SD)	Post-Treatment (t2) M (SD)	6-Month Follow-Up (t3) M (SD)	12-Month Follow-Up (t4) M (SD)
Perceived Stress (PSS-10)				
n with valid data	121	106	99	93
STEP	17.66 (6.07)	16.50 (7.60)	15.46 (7.39)	16.51 (7.46)
MBCT	16.34 (6.56)	14.10 (6.25)	15.13 (6.55)	12.99 (6.14)
Cortisol Slope				
n with valid data	136	121	115	100
STEP	0.296 (0.063)	0.283 (0.071)	0.310 (0.087)	0.287 (0.089)
MBCT	0.298 (0.062)	0.285 (0.103)	0.325 (0.139)	0.309 (0.094)

Note. Possible range of scores on PSS-10: 10 to 40; STEP = supportive sex education and therapy group; MBCT = mindfulness-based cognitive therapy group

Table 3 Time and Group Comparisons and Interaction Effects from Random Coefficient Analysis Models for the Stress Measures at Pre-treatment (t1), Post-treatment (t2), 6-Month Follow-up (t3), and 12-Month Follow-up (t4)

Variable	b	SE	p	d	95% CI for b
Model for perceived stress: PSS-10					
Constant	17.87	0.79	<0.001***		16.32, 19.43
Time (t2-t1)	-1.36	0.62	0.030*	-0.21	-2.58, -0.13
Time (t3-t1)	-1.40	0.64	0.029*	-0.22	-2.65, -0.14
Time (t4-t1)	-1.66	0.65	0.011*	-0.26	-2.94, -0.38
Group	-1.76	1.02	0.086	-0.28	-3.78, 0.25
Time (t2-t1) X Group	-0.81	1.23	0.510	-0.13	-3.23, 1.60
Time (t3-t1) X Group	1.35	1.26	0.282	0.21	-1.12, 3.82
Time (t4-t1) X Group	-2.58	1.28	0.045*	-0.41	-5.10, -0.06
Model for cortisol slope					
Constant	0.303	0.017	<0.001***		13.39, 17.70
Time (t2-t1)	-0.011	0.008	0.197	-0.17	-0.027, 0.006
Time (t3-t1)	0.026	0.008	0.003**	0.40	0.009, 0.045
Time (t4-t1)	-0.002	0.009	0.796	-0.04	-0.019, 0.015
Group	0.012	0.012	0.303	0.19	0.011, 0.035
Time (t2-t1) X Group	-0.001	0.016	0.944	-0.02	-0.033, 0.031
Time (t3-t1) X Group	0.009	0.017	0.596	0.14	-0.024, 0.041
Time (t4-t1) X Group	0.007	0.017	0.680	0.11	-0.026, 0.040

Note. t1 = pre-treatment; t2 = posttreatment; t3 = 6-month follow-up; t4 = 12-month follow-up; group estimate = MBCT minus STEP; CI = confidence interval; d = Cohen's d based on the multi-level model estimates. All models included random intercepts. * $p < .05$, ** $p < .01$, *** $p < .001$

Fig. 2 Cortisol slopes (AM to PM) for each time point across STEP and MBCT groups

the two treatment arms. Moreover, the significant treatment effect seen at t3 was not retained at 12-month follow-up (t4) (Table 3).

Perceived stress as a potential mediator of improvements in sexual desire and sex-related distress

Our exploratory multilevel analyses found that both path a and path b coefficients (Fig. 1) were significant, indicating that there was significant change in the mediators following treatment ($B = -1.249$, $p < .001$) and that changes in the mediators were significantly associated with changes in

the outcomes ($B = -0.474$, $p = .003$ and $B = 0.753$, $p < .001$, for SIDI and FSIDS-R, respectively). All effects were in the predicted direction: treatment led to reductions in perceived stress and reductions in perceived stress predicted the increase in sexual desire (SIDI) and decrease in sex-related distress (FSIDS-R).

The moderating effect of treatment on path a (changes in the mediator post-treatment) was significant ($B = -1.686$, $p = .050$ estimate for the interaction of treatment and time predicting perceived stress), indicating a greater reduction in perceived stress in the MBCT than in the STEP group. In addition, the moderating effect of treatment on path b (changes in mediators predicting changes in SIDI and FSIDS-R) was significant for sexual desire ($B = -0.623$,

$p = .007$ estimate for interaction of treatment and perceived stress predicting SIDI), indicating that the reduction in perceived stress predicted increases in sexual desire for the MBCT group only. These results indicate the presence of moderated mediation for both outcomes (SIDI and FSRS-R). For sexual desire, both path a and path b are moderated, and for sexual distress, moderation is present in path a.

The significance and size of mediation effects tested using bootstrap analysis are presented in Table 4. The 95% one-way confidence intervals for indirect effect estimates indicate that the decrease in perceived stress mediated improvements in sexual desire and sex-related distress, but only for the MBCT group. Mediating effects explained 12% of the variance for each outcome.

Discussion

Overall, both MBCT and STEP treatments led to significant improvements in self-reported stress, with significantly greater improvements after MBCT compared to STEP. The medium effect size improvement in perceived stress in the MBCT group is consistent with other findings examining similar impacts of mindfulness interventions (Venkatesan et al., 2021; Zollars et al., 2019). In addition, the cortisol slope was steeper from baseline to 6-month follow-up, pointing to improved HPA axis regulation, with no differences between the two treatment arms. We also found that improvements in self-reported stress mediated improvements in sexual desire and sex-related distress, but only after MBCT.

Numerous studies have identified stress as a significant factor associated with lower sexual functioning (Basson et al., 2019; Hamilton & Julian, 2014; Traeen et al., 2007), negatively impacting sexual arousal as measured

by laboratory-based assessment (Hamilton et al., 2013; ter Kuile et al., 2007), relationship quality (Bodenmann et al., 2006; Harper et al., 2000; Neff & Broady, 2011), and cognitive and emotional factors associated with sexual response (Hamilton & Meston, 2013; Nobre, 2009). Our results suggest that MBCT adapted to women with low desire, with a focus on building skills in equanimity and interoceptive awareness, as well as providing group support and psychoeducation, has positive impacts on both psychological and physiological aspects of stress, as well as positive impacts on sexual desire and sexual distress (Brotto et al., 2021).

Mindfulness-based interventions have been consistently shown to decrease self-reported stress, in both clinical and non-clinical populations (Ameli et al., 2020; Baer et al., 2012). One possible mechanism by which this approach may decrease self-reported stress is through training interoceptive awareness with equanimity. Specifically, experiential avoidance (a self-regulatory tendency to avoid negative thoughts, feelings, memories, physical sensations, and other internal experiences) has been found to be a significant risk factor for elevated perceived stress (Allen, 2021; Martínez-Rubio et al., 2023). Mindfulness practices that emphasize training of equanimity directly address this by cultivating the ability to experience even unpleasant sensations (including thoughts) without resentment or avoidance. Equanimity was found to be the key mediator in reduction of psychological distress during an 8 week group Mindfulness integrated Cognitive Behavioral Therapy intervention in a heterogeneous primary health care population (Francis et al., 2022). Other studies have highlighted the role of non-reactivity, a proxy measure of equanimity, in decreasing perceived stress (Mayer et al., 2019). Our results suggest that mindfulness practices that emphasize training of equanimity toward hedonic tone of internal experience may contribute toward improvements in sexual distress and sexual desire perhaps through reductions in stress. There is also evidence that mindfulness training improves sexual desire and sexual distress through the mechanism of improved interoceptive awareness (Brotto et al., 2023), which further supports a potential role of mindfulness in reducing stress among those with sexual dysfunction.

It is noteworthy that MBCT was more effective than STEP in decreasing perceived stress, and that the reduction in perceived stress predicted increases in sexual desire and decreases in sex-related distress only for participants in the MBCT group. By contrast, both the MBCT and STEP treatments resulted in steeper diurnal cortisol slopes, indicating better HPA regulation, at the 6 month follow-up regardless of arm. As MBCT is known to play a role in regulating stress both psychologically and physiologically (Aguilar-Raab et al., 2021; Ho et al., 2020), it was hypothesized that those randomized to the MBCT group would show greater

Table 4 Bootstrap Results for Moderated Mediation Indirect Effect

Mediator	Sexual Desire (SIDI)		Sexual Distress (FSRS-R)	
	Indirect effect (One-way 95% CI)	% of Total effect explained by indirect effect	Indirect effect (95% CI)	% of Total effect explained by indirect effect
Perceived Stress				
STEP	0.05 (-0.33, 0.55)	1%	-0.15 (-0.85, 0.48)	1%
MBCT	1.28 (0.06, 3.04)	12%	-1.28 (-3.04, -0.04)	12%

Note. CIs not including zeros are in bold. STEP = supportive sex education and therapy group; MBCT = mindfulness-based cognitive therapy group; SIDI = Sexual Interest and Desire Inventory; FSRS-R = Female Sexual Distress Scale-Revised

improvements in self-reported stress, and a steeper cortisol slope from pre- to post-treatment than those randomized to STEP; however, of note, we have no previous evidence to suggest that STEP would not also regulate stress responsivity. That the slopes were similar may indicate that when there is one major stressor (e.g., sexual dysfunction), effectively lessening its severity (as occurred in both treatment groups) can have a particularly powerful beneficial effect on stress physiology. However, how stressed the women felt may be influenced by other emotions. The greater reduction in perceived stress in the MBCT group may well reflect their increase in equanimity (i.e., reduced reactivity to stressors).

An extensive review and meta-analysis of associations between diurnal cortisol slopes and both physical and mental health (Adam et al., 2017) provides considerable evidence that the diurnal cortisol slope is both sensitive to emotional and psychosocial stress and related to health outcomes; i.e., a flattened cortisol slope across the day was shown to be associated with both adverse experiences and worse health outcomes, including immune and inflammatory system dysregulation, depression symptoms and disorders, cancer, and obesity. Importantly, cortisol is not only a critical hormone in the stress response system, but has physiological effects on multiple body systems, including metabolic processes, skeletal muscle function, the nervous system (mood, arousal, behavior), immune function and inflammation, and secretion of other hormones (Chrousos & Gold, 1992; Sapolsky et al., 2000). Thus, HPA dysregulation, as indexed by the diurnal cortisol pattern, will impact the function of major peripheral and central systems, which could, in turn, contribute to adverse health outcomes. We suggest that the moderate effect size for the change in cortisol slope from t1 to t3 in our study is clinically significant, given that it compares favorably with the effect sizes reported in Adam et al. (2017). Whether a flatter diurnal cortisol slope is a mechanism underlying the development of diseases, a symptom or consequence of disease, or both a symptom and a consequence remains to be determined. Future research into associations between both disturbed and improved parameters of stress physiology and progression of stress-related diseases will be welcome.

There is also some evidence that mindfulness-based interventions and other active treatment arms led to the same changes in diurnal cortisol slope in cancer patients (Carlson et al., 2013), or in fibromyalgia (Cash et al., 2015). While both treatments decreased self-reported stress in association with improved HPA regulation (i.e., steeper diurnal cortisol slope), a greater reduction in perceived stress was afforded by MBCT which in turn predicted increases in sexual desire and decreases in sex-related distress for participants in that group in our study.

The improvement in HPA regulation, as measured by the steeper diurnal slope observed after both treatments at 6 months, was no longer statistically significant at the 12 month follow-up. By contrast, the improvement in both perceived stress and sexual desire (Brotto et al., 2021) were maintained at the 12-month follow-up. This suggests that treatment may have directly impacted HPA regulation and directly but independently improved sexual function and perceived stress. Mindfulness, supportive therapy, and learning psychological skills are known to both lessen stress and improve sexual function. At 12 months, the continued relief from their improved sexual response (as indicated by maintained reduction in sexual distress scores; Brotto et al., 2021) may have lessened the impact of participants' other stressors as reflected in their sustained lower perceived stress scores. In turn this continued reduction in stress may have supported the improvement in sexual desire thus creating a positive self-perpetuating cycle. There is also evidence that diurnal cortisol slope stability estimates over time are quite modest, and suggest that it may be more indicative of a state rather than trait (Ross et al., 2014).

There are limitations to this study that need to be considered. First, we used a brief 10-item scale to capture participants' perceived stress, and this may not have reflected the full spectrum of their stressful life experiences. Our measure of HPA axis dysregulation was the cortisol slope over the day, and we relied on participants accurate compliance with the procedures for providing saliva samples; however, since these biospecimens were collected at home, it is not possible to verify whether all procedures were followed. As time of day is a critical factor influencing cortisol levels (Adam et al., 2017), a deviation from the set saliva collection times could have influenced the cortisol slope observed. Importantly, detailed contextual and relational factors in the participants' sexual difficulties were not assessed, and how such factors may have interacted both with treatment (through MBCT and STEP) and stress response (both self-reported and cortisol slope) are unknown.

Conclusions

In conclusion, both an 8-week group MBCT adapted for women with SIAD and supportive sex education significantly improved HPA axis regulation and reduced self-reported symptoms of stress at 6 months post treatment, and improvements in self-reported stress were greater with MBCT than with STEP, whereas the two groups were equivalent in their positive impact on diurnal cortisol slope. In turn, the reduction in stress symptoms mediated improvements in sexual desire and sex-related distress afforded by MBCT. Given these improvements from both treatment

modalities, either treatment may be considered for women presenting for treatment for low sexual desire who concurrently experience significant stress.

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Declarations

Competing interests The authors have no competing interests to disclose.

Ethical approval The study was approved by the Clinical Research Ethics Board of the University of British Columbia (H12-01659) as well as the Vancouver Coastal Health Research Institute Ethics Board. All participants provided written informed consent prior to participating. The study was pre-registered at ClinicalTrials.gov NCT01690897. The data and code are housed at https://osf.io/6wmgf/?view_only=cfb7e40581aa4d80bb85b6376c892ac4.

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