

## Community-Delivered Heated Hatha Yoga as a Treatment for Depressive Symptoms: An Uncontrolled Pilot Study

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### Abstract

**Objectives:** There are no known studies of concurrent exposure to high temperature and yoga for the treatment of depression. This study explored acceptability and feasibility of heated (Bikram) yoga as a treatment for individuals with depressive symptoms.

**Design:** An 8-week, open-label pilot study of heated yoga for depressive symptoms.

**Subjects:** 28 medically healthy adults (71.4% female, mean age 36 [standard deviation 13.57]) with at least mild depressive symptoms (Hamilton Rating Scale for Depression [HRSD-17] score  $\geq 10$ ) who attended at least one yoga class and subsequent assessment visit.

**Intervention:** Participants were asked to attend at least twice weekly community held Bikram Yoga classes. Assessments were performed at screening and weeks 1, 3, 5, and 8. Hypotheses were tested using a modified-intent-to-treat approach, including participants who attended at least one yoga class and subsequent assessment visit ( $N=28$ ).

**Results:** Almost half of our subjects completed the 8-week intervention, and close to a third attended three quarters or more of the prescribed 16 classes over 8 weeks. Multilevel modeling revealed significant improvements over time in both clinician-rated HRSD-17 ( $p=0.003$ ;  $d_{GLMM}=1.43$ ) and self-reported Beck Depression Inventory (BDI;  $p<0.001$ ,  $d_{GLMM}=1.31$ ) depressive symptoms, as well as the four secondary outcomes: hopelessness ( $p=0.024$ ,  $d_{GLMM}=0.57$ ), anxiety ( $p<0.001$ ,  $d_{GLMM}=0.78$ ), cognitive/physical functioning ( $p<0.001$ ,  $d_{GLMM}=1.34$ ), and quality of life ( $p=0.007$ ,  $d_{GLMM}=1.29$ ). Of 23 participants with data through week 3 or later, 12 (52.2%) were treatment responders ( $\geq 50\%$  reduction in HRSD-17 score), and 13 (56.5%) attained remission (HRSD score  $\leq 7$ ). More frequent attendance was significantly associated with improvement in self-rated depression symptoms, hopelessness, and quality of life.

**Conclusions:** The acceptability and feasibility of heated yoga in this particular sample with this protocol warrants further attention. The heated yoga was associated with reduced depressive symptoms, and other improved related mental health symptoms, including anxiety, hopelessness, and quality of life.

**Keywords:** yoga, heated yoga, depression, major depressive disorder (MDD), heat, hyperthermia

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## Introduction

DEPRESSIVE DISORDERS ARE ASSOCIATED with significant morbidity.<sup>1</sup> The largest study of standard antidepressant treatment outcomes in major depressive disorder (MDD) reported an overall cumulative remission rate of only 67% for a multistep treatment involving both antidepressant medications and cognitive therapy,<sup>2</sup> which may be lower, depending on the outcome measure reported.<sup>3</sup> This reinforces the need for novel treatments. Heated yoga, an intervention that combines yoga and heat (the latter effectively a form of whole body hyperthermia [WBH]), is an understudied but increasingly popular and promising area for intervention research.

There has been mounting evidence that yoga has antidepressant effects. Two meta-analyses—one comprising 12 studies of adults with depressive symptoms<sup>4</sup> and the other including 7 studies of adults with MDD<sup>5</sup>—suggested that yoga may be effective for treating depression. A lack of rigorous methodology (e.g., lack of standard reporting, *a priori* sample size calculations, randomization, allocation concealment, intention-to-treat analyses, blinding) prevents more definitive conclusions.<sup>5,6</sup> Another limitation of the literature is the broad range of yoga styles employed, differing in postures, duration, and practice conditions, which limits the generalizability of findings.

Recent pilot evidence demonstrated that WBH, at temperatures similar to those offered in some forms of heated yoga (i.e., Bikram yoga [BY]), has antidepressant effects.<sup>7,8</sup> In a double-blind randomized controlled trial (RCT), 34 medication-free patients with MDD were randomized to a single WBH session (temperature = 38.5°C/101.3°F) versus a plausible sham involving a lower temperature exposure.<sup>7</sup> Participants receiving WBH demonstrated reduced depression scores, with greater effect sizes ( $d = 2.23$ – $1.66$ , weeks 1–6 post treatment) than typically observed in antidepressant trials.<sup>7</sup> The authors hypothesized that thermoregulatory cooling system dysregulation in depressed patients may be targeted by WBH.<sup>7–9</sup>

While the above studies might hypothetically suggest that the combination of yoga postures and heat may have additive or synergistic antidepressant effects, heated yoga has not yet been studied as a treatment for depression. BY is a popular heated yoga practice comprising 26 postures and 2 breathing exercises, with most postures performed twice in sequence during a 90-min session (Table 1).

Three studies of BY have been conducted among individuals experiencing high stress. In an uncontrolled study of 51 individuals, BY was associated with increased mindfulness and decreased stress.<sup>10</sup> In an RCT of adult females with high perceived stress scores, dietary restraint, and emotional eating, BY demonstrated significant effects on perceived stress, stress reactivity, distress tolerance, and disordered eating behaviors relative to a waitlist control.<sup>11,12</sup> In another RCT with stressed adults, BY (compared to a no treatment control) was associated with significant decreases in perceived stress, self-efficacy, and two domains of health-related quality of life.<sup>13</sup> While these studies support the mental health benefits of heated yoga, no studies to date have evaluated its effects on depressive symptoms in clinical populations.

The purpose of this study is to investigate for the first time the acceptability and feasibility of heated yoga as a treatment of depression and explore its association with depressive symptoms. We hypothesized that heated yoga would be well

TABLE 1. BIKRAM YOGA SERIES

<i>Posture name in Sanskrit</i>	<i>Posture name in English</i>
Standing series	
1 Pranayama	Standing deep breathing
2 Ardha-Chandrasana and Pada-Hasthasana	Half moon pose and hands to feet
3 Utkatasana	Awkward
4 Garurasana	Eagle
5 Dandayamana-Janushirasana	Standing head to knee
6 Dandayamana-Dhanurasana	Standing bow pulling
7 Tuladandasana	Balancing stick
8 Dandayamana-Bibhaktapada-Paschimotthanasana	Standing separate leg stretching
9 Trikanasana	Triangle
10 Dandayamana-Bibhaktapada-Janushirasana	Standing separate leg head to knee
11 Tadasana	Tree
12 Padangustasana	Toe stand
Floor series	
13 Savasana	Dead body
14 Pavanamuktasana	Wind removing
15 Yoga Sit-Up	Yoga sit-up
16 Bhujangasana	Cobra
17 Salabhasana	Locust
18 Poorna-Salabhasana	Full locust
19 Dhanurasana	Bow
20 Supta-Vajrasana	Fixed firm
21 Ardha-Kurmasana	Half tortoise
22 Ustrasana	Camel
23 Sasangasana	Rabbit
24 Janushirasana with Paschimotthanasana	Head to knee
25 Ardha-Matsyendrasana	Spine twisting
26 Khapalbhati	Blowing in firm

received by a depressed population, and that attending heated yoga classes would be associated with significant decreases in depressive symptom severity, and improvements in other related constructs, including hopelessness, anxiety, quality of life, and cognitive and physical functioning.

## Materials and Methods

### Study design

This study examined the acceptability, feasibility, and the association with depressive symptoms of an open-label BY intervention for medically healthy participants with clinically significant depressive symptoms. Patients were asked to attend at least two community held (already existing) BY classes per week for 8 weeks in either of two community BY studios (under the same ownership). This was a first-step study to explore this potential modality of treatment, which allowed for “all comers”—in that, the study explored BY as both a monotherapy (alone without medications) and as an augmentation (in addition to stable, established use of medication and/or psychotherapy). The inclusion of both groups allowed for greater generalizability to reflect real-world populations.

### Participants

Participants were recruited through the Depression Clinical and Research Program (DCRP) at the Massachusetts

General Hospital (MGH) (e.g., through flyers and on-line advertisements) and through the participating yoga studios' websites and posted flyers. The Partners Human Research Committee Institutional Review Board (IRB) approved this protocol, and written informed consent was obtained before participation. Research visits were conducted at the DCRP.

Inclusion criteria: 18–65 years of age; depressive symptoms in at least the mild range (Hamilton Rating Scale for Depression [HRSD-17] total score  $\geq 10$ ).<sup>14</sup>

Exclusion criteria: substance abuse or dependence within the last 6 months; epilepsy, history of an abnormal electroencephalogram (EEG), severe head trauma, or stroke; lifetime history of psychosis or mania; current eating disorder; serious or uncontrolled medical conditions that could make participation unsafe; current active suicidal ideation or self-injurious behavior; electroconvulsive therapy within the past year; plans to become pregnant; participation in any single heated yoga session within the past 12 weeks; or any regular yoga practice ( $\geq 3$  sessions per week for  $\geq 1$  month) within the past year. Concurrent treatment for depression was allowed, provided it was not recently initiated or altered during the study; this included established psychotherapy (at least 3 months) and/or stable psychotropic medications/doses (at least 4 weeks).

### Intervention

Participants were provided with a free-of-charge, 8-week unlimited memberships to two Boston-area BY studios and were asked to attend at least two classes per week for 8 weeks. Research staff and the co-owners of two study-affiliated yoga studios (Jill, Brad, and Tomo Koontz) met before beginning the study to ascertain fidelity of the study intervention delivery. Patients were given the option to attend classes at both studios interchangeably (one location in Boston, one in Cambridge), and were informed of the studios' locations before entering the study to assure the accessibility of the classes. Both were readily accessible by public transportation.

BY provides a standardized intervention consisting of 26 sequenced postures (*asanas*) and two breathing exercises (*pranayama*), practiced for 90 min in a room heated to 105°F with 40% relative humidity. Please see Table 1 for a full list of the postures. The sequence is administered by trained instructors who follow a standardized dialogue and postures are held for the same duration in each class. BY instructors were trained and certified during an intensive 9-week teacher-training program at Bikram's Yoga College of India and are recertified every 3 years.<sup>15</sup> The participating studios were in compliance with BY certification requirements. Intervention adherence was tracked using attendance data collected through a computerized system at the studios, transmitted to study staff via HIPAA-compliant means (i.e., via "SEND SECURE," an institutional encrypted e-mail system for recipients outside the institutional firewall). Before their first BY class, participants completed a 50-min psychoeducational visit outlining expectations for this form of yoga and tips for practice.

### Instruments and assessments

Assessments were completed at screen (referred to as "baseline" in analyses) and weeks 1, 3, 5, and 8 and 3 months following the first session. Self-report measures were com-

pleted via paper-and-pencil. Clinician-rated instruments were completed by a total of 12 psychiatrists, clinical psychologists, or supervised MD or PhD-level trainees. Psychiatric diagnoses were obtained at screening using the Structured Clinical Interview for the Diagnostic and Statistical Manual of Mental Disorders, 4th Edition (SCID).<sup>16</sup>

**Primary outcome measures.** Feasibility and acceptability were assessed by attendance data and completion rates. The Structured Interview Guide for the HRSD-17<sup>14,17</sup> was used to measure past-week depressive symptoms. Item ratings were summed for the first 17 items, with total scores indicating HRSD: not depressed (0–7), mildly depressed (8–16), moderately depressed (17–23), and severely depressed ( $\geq 24$ ).<sup>18</sup> Our group's clinicians routinely score observed recorded video interviews using the HRSD-17 with clinicians and actors as patients, with a current interrater reliability of 0.97 (Intraclass Correlation Coefficient). Self-report ratings of depression over the past week were measured with the Beck Depression Inventory (BDI), which included 21 items rated on a scale from 0 to 3.<sup>19</sup> Item ratings were summed to form total scores indicating normal (0–7), mild (8–13), moderate (14–18), severe (19–22), or very severe ( $>22$ ) depression.<sup>20</sup>

**Secondary outcome measures.** Valid and reliable measures were administered for constructs frequently associated with depression: hopelessness, anxiety, quality of life, and functional impairment. Hopelessness was measured with the Beck Hopelessness Scale (BHS), a self-report scale measuring negative attitudes about the future.<sup>21</sup> The BHS includes 20 true/false statements. True responses are summed to form a total score indicating none or minimal (0–3), mild (4–8), moderate (9–14), or severe (14–20) hopelessness. Anxiety symptoms were assessed with the Beck Anxiety Inventory (BAI), a self-report instrument.<sup>22</sup> The BAI includes 21 items rated on a scale from 0 to 3. Total scores indicate minimal (0–7), mild (8–15), moderate (16–25), or severe (26–63) anxiety symptoms. Quality of life was measured with the Quality of Life Enjoyment and Satisfaction Questionnaire (QLESQ)-Short Form, a self-report instrument that assesses on a 1–5 scale, 13 specific areas of life including physical health, general feelings of wellbeing, work satisfaction, leisure activities, social relationships, medication, and overall life satisfaction over the past week.<sup>23</sup> Higher scores indicate greater wellbeing. Functional impairment was assessed using the Massachusetts General Hospital Cognitive and Physical Functioning Questionnaire (CPFQ), a 7-item questionnaire that assesses difficulties with energy, alertness and cognition.<sup>24</sup> Higher scores indicate greater impairment.

Alphas for the scales (not including the clinician-rated [HRSD] and dichotomous [BHS]) were as follows: BDI = 0.803; BAI = -0.841; QLESQ = 0.662; and CPFQ = 0.887.

### Data analysis

SPSS version 20.0 (SPSS, Inc., Chicago, IL) was used to complete all analyses. Feasibility and acceptability data (i.e., attendance and completion rates) were calculated using frequency data. Study hypotheses were tested by multilevel modeling (MLM), using restricted maximum-likelihood estimation and with repeated measures error covariance modeled as auto-regressive [AR(1)]. MLM is preferred for

analyzing longitudinal data because it reduces bias due to participant dropout by including all participants regardless of missing data.<sup>25</sup> A modified intent-to-treat approach was used; participants who attended at least one yoga class over the course of the study and one additional assessment following the baseline (BL) visit were included in the analyses. All analyses controlled for: (1) age (continuous); (2) use of antidepressants and other psychotropic medication (dichotomous); (3) baseline scores on the outcome measures (continuous); (4) and yoga attendance (i.e., intervention adherence; continuous). Time was centered at post-treatment (week-8), and standard (z) scores were used for all continuous covariates, to facilitate interpretation of  $\beta$  and  $p$ -values for main effects. Effect sizes were calculated per Feingold's recommendations for calculating and reporting effect sizes for linear mixed models [ $d_{GLMM} = (b_{TIME} \times duration) / SD_{BL}$ ].<sup>26</sup> Effect sizes for pre- to post-intervention change were also calculated by Cohen's  $d$  for repeated measures, using Morris and DeShon's equation (8) [ $d_{RM} = M_{diff} / \sigma \sqrt{2(1-r)}$ ].<sup>27</sup> To examine the effects of yoga attendance on degree of symptom change over time, *post hoc* analyses were conducted, adding a time-by-attendance interaction term to the MLM models above.

## Results

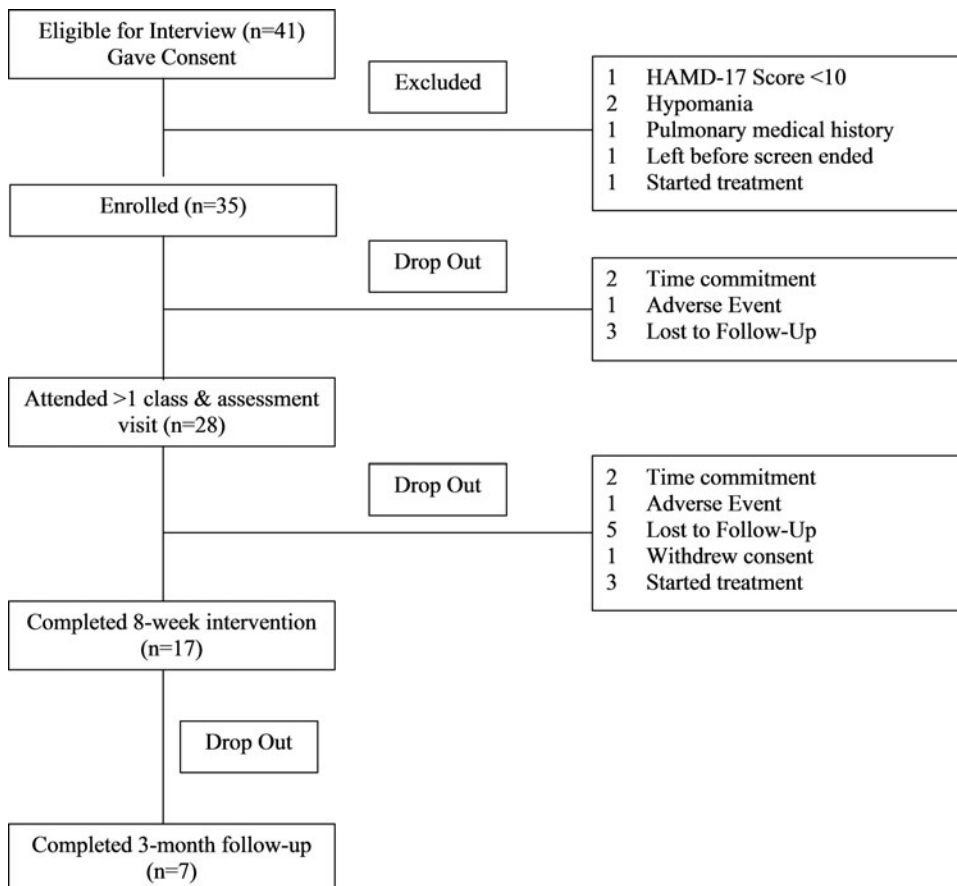
### Preliminary analyses

**Participant characteristics.** A summary of participant flow is as follows: 41 gave consent, 35 met study eligibility, and 28 attended at least 1 yoga class and a subsequent assessment visit (Fig. 1). Participant demographics and baseline clinical

characteristics (including psychotropic medication use) are provided in Table 2. Twenty-six participants (92.9%) met criteria for current MDD based on the SCID. The two participants who did not meet criteria for MDD scored 11 and 12 on the HRSD-17 and 5 and 18 on the BDI. Both met criteria for current minor depressive disorder and had met criteria for MDD in the past. At screening, average depression severity was in the moderate range, based on clinician- and self-ratings. Table 3 provides means and standard deviations (SDs) for study variables at each time point.

### Feasibility: Retention and adherence to Bikram yoga intervention

Participants attended between 1 and 22 ( $M=8.71$ ,  $SD=5.45$ ) classes over the 8-week intervention period. Only 3 (10.7%) participants met or exceeded the recommended study dose of 16 sessions over 8 weeks (Fig. 1). Intervention retention rates by week, along with the actual number of participants who attended at least one BY class, are shown in Figure 2. Reasons for dropouts (per clinician study notes): (1) worsening of pre-existing condition (i.e., shoulder, back, post-traumatic stress disorder [PTSD] symptoms); (2) time commitment (i.e., started school, work stress), (3) difficulty adjusting to the practice; (4) change in treatment regimen (e.g., therapy initiated, aripiprazole augmentation (caused increased heat sensitivity), (5) adverse reactions to BY (e.g., dehydration symptoms [lightheadedness], hypoglycemia); (6) did not like BY ("did not find it relaxing"); (7) difficulty getting to yoga (i.e., due to winter weather); and (8)



**FIG. 1.** CONSORT chart. CONSORT, Consolidated Standards of Reporting trials.

TABLE 2. BASELINE DEMOGRAPHICS AND CLINICAL CHARACTERISTICS OF THE SAMPLE (N=28)

Characteristic	Mean (SD)		n	%
	Range			
Age	19–64	36.46 (13.57)		
Gender				
Male			8	28.6
Female			20	71.4
Race/ethnicity				
White			18	64.3
African American			5	17.9
American Indian or Alaskan Native			1	3.6
More than one selected			3	10.7
No response			1	3.6
Ethnicity				
Hispanic/Latina			11	39.3
Non-Hispanic/Latina			14	50.0
No response			3	10.7
Education				
Graduate			7	25.0
Part graduate/professional school			3	10.7
Undergraduate			9	32.1
Part undergraduate/2-year degree			6	21.4
High school			2	7.1
No response			1	3.6
Marital status				
Never married			14	50.0
Married or living with someone			6	21.4
Separated or divorced			3	10.7
No response			5	17.9
Employment				
Full time			13	46.4
Part time			4	14.3
Student			5	17.9
Not currently employed (e.g., laid off, leave of absence, homemaker, retired)			6	21.4
Current psychotropic medication use (i.e., ≥1 of the following: fluoxetine, bupropion, mirtazapine, lamotrigine, venlafaxine, citalopram, duloxetine)			6	21.4
Anxiety disorder diagnosis, per SCID criteria <sup>16</sup>				
One diagnosis			7	25.0
Two diagnoses			2	7.1
Generalized anxiety disorder			4	14.3
Panic disorder			3	10.7
Posttraumatic stress disorder			1	3.6
Social anxiety disorder			1	3.6
Specific phobia			1	3.6
Anxiety disorder, NOS			1	3.6

NOS, not otherwise specified; SD, standard deviation; SCID, Structured Clinical Interview for the Diagnostic and Statistical Manual of Mental Disorders, 4th edition.

depressive symptoms interfered (e.g., motivation and cognitive impairment).

#### Main effects of change in depression and related symptoms

**Primary depression measures.** Clinician-rated HRSD-17 depression severity decreased significantly from baseline to

week 8 [ $b=-1.71$ ,  $t(82)=-3.05$ ,  $p=0.003$ , 95% confidence interval, CI (-2.83 to -0.59),  $d_{GLMM}=1.43$ ;  $d_{RM}=1.35$ ]. Self-reported depression severity, per the BDI, significantly decreased over time [ $b=-2.41$ ,  $t(92)=-5.00$ ,  $p<0.001$ , 95% CI (-3.37 to -1.46),  $d_{GLMM}=1.31$ ;  $d_{RM}=1.10$ ].

**Secondary depression measures.** There were significant changes over time in each of the secondary outcome measures. Participants' self-reported hopelessness [ $b=-0.70$ ,  $t(90)=-2.29$ ,  $p=0.024$ , 95% CI (-1.31 to -0.09),  $d_{GLMM}=0.57$ ;  $d_{RM}=0.36$ ], anxiety [ $b=-1.58$ ,  $t(78)=-3.67$ ,  $p<0.001$ , 95% CI (-2.43 to -0.72),  $d_{GLMM}=0.78$ ;  $d_{RM}=1.28$ ], quality of life [ $b=1.80$ ,  $t(91)=2.78$ ,  $p=0.007$ , 95% CI (0.51 to 3.08),  $d_{GLMM}=1.29$ ;  $d_{RM}=0.71$ ], and functional impairment [ $b=-2.04$ ,  $t(95)=-5.72$ ,  $p<0.001$ , 95% CI (-2.74 to -1.33),  $d_{GLMM}=1.34$ ;  $d_{RM}=1.30$ ] each improved over the course of the intervention period.

#### Effects of degree of yoga attendance on symptom change

Improvements in self-reported anxiety and cognitive and physical functioning did not vary by number of yoga classes attended [BAI:  $b=-0.29$ ,  $t(74)=-0.63$ ,  $p=0.532$ ; CPFQ:  $b=-0.11$ ,  $t(92)=-0.30$ ,  $p=0.769$ ], and a nonsignificant effect of attendance was also observed for reduction in clinician-rated depression symptoms [ $b=-1.10$ ,  $t(79)=-1.89$ ,  $p=0.063$ ]. More frequent attendance was significantly associated with greater improvements in self-reported depression [ $b=-1.80$ ,  $t(87)=-3.74$ ,  $p<0.001$ ], hopelessness [ $b=-0.66$ ,  $t(84)=-2.11$ ,  $p=0.038$ ], and quality of life [ $b=2.39$ ,  $t(90)=3.61$ ,  $p=0.001$ ].

To estimate the frequency of yoga required for outcome improvement, models were re-run with the attendance variable centered at four different attendance rates: (1) once every 2 weeks (4 classes in total), (2) once a week (8 classes in total), (3) 1.5 classes per week (12 classes in total), and (4) 2 classes per week (16 classes in total).<sup>28,29</sup> Significant improvements in clinician-rated depression [ $b=-1.22$ ,  $t(82)=-2.02$ ,  $p=0.047$ ] and self-reported depression [ $b=-1.60$ ,  $t(89)=-3.24$ ,  $p=0.002$ ] were achieved by participants who attended yoga at least once per week. Self-reported hopelessness [ $b=-0.89$ ,  $t(86)=-2.83$ ,  $p=0.006$ ] and quality of life [ $b=2.64$ ,  $t(91)=4.03$ ,  $p<0.001$ ] significantly improved among participants who attended at least 1.5 classes per week (12 sessions total).

#### Treatment response and remission rates (per HRSD-17)

Response and remission rates were examined based on last assessments in all subjects who completed an assessment at week 3 and/or later (i.e., participants who did not have assessments for weeks 3, 5, and 8 were excluded). Twenty-three participants were analyzed, using data from their last assessment point: week 8 ( $n=17$ ), week 5 ( $n=3$ ), or week 3 ( $n=3$ ). Of these 23 participants, 12 (52.2%) were responders (≥50% reduction in total HRSD-17 score) and 13 (56.5%) were remitters (final HRSD-17 score ≤7).

Among "low attenders" (i.e., <5 classes attended over 8 weeks;  $n=3$ ), all dropped out of the yoga intervention by the start of week 3, and none responded or remitted. Among "average attenders" (6–10 classes;  $n=11$ ), five responded (45.5%) and six remitted (54.5%). Among "above average

TABLE 3. DESCRIPTIVE STATISTICS AT EACH ASSESSMENT POINT

	Screen (n=28) Mean (SD)	Week 1 (n=27) Mean (SD)	Week 3 (n=23) Mean (SD)	Week 5 (n=19) Mean (SD)	Week 8 (Post-Tx; n=17) Mean (SD)
Total BY classes attended					8.71 (5.45)
Clinician-rated depression (HRSD-17)	17.68 (4.78)	13.56 (5.47)	11.74 (5.88)	12.63 (15.72)	8.18 (5.76)
Self-reported depression (BDI)	20.44 (7.34)	17.27 (7.46)	14.10 (9.23)	12.11 (9.96)	10.12 (10.41)
Hopelessness (BHS)	9.54 (4.89)	8.27 (4.58)	7.64 (5.83)	6.63 (6.19)	7.47 (6.72)
Anxiety (BAI)	12.21 (8.06)	10.81 (7.21)	8.33 (6.94)	6.28 (6.19)	6.06 (6.78)
Cognitive and physical functioning (CPFQ)	25.50 (6.08)	22.92 (6.10)	21.81 (6.78)	19.17 (7.25)	17.38 (5.73)
Quality of life (QLESQ) <sup>a</sup>	37.50 (5.59)	39.35 (7.94)	44.86 (9.50)	44.05 (14.14)	45.88 (13.08)

<sup>a</sup>Higher scores indicate improvement.

BAI, Beck Anxiety Inventory; BDI, Beck Depression Inventory; BHS, Beck Hopelessness Scale; BY, Bikram Yoga; CPFQ, Cognitive and Physical Functioning Questionnaire; HRSD-17, Hamilton Rating Scale for Depression; QLESQ, Quality of Life Enjoyment and Satisfaction Questionnaire; SD, standard deviation.

attenders" (11–14 classes total;  $n=6$ ), four (66.7%) responded and five (83.3%) remitted. All three (100%) high attenders (18–20 classes total) responded and two (66.7%) remitted.

#### Intervention effects for participants with MDD ( $N=26$ )

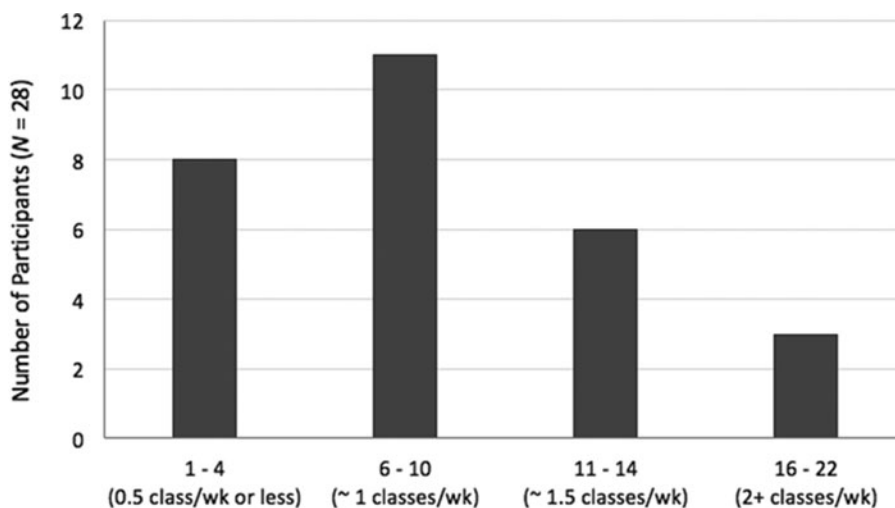
Since 26 of 28 subjects met criteria for MDD, a *post hoc* analysis of these subjects was conducted. When excluding the two participants who did not meet baseline criteria for MDD, each of the main effects of time held. Thus, the findings for participants meeting criteria for MDD ( $n=26$ ) were identical to those for the entire sample ( $N=28$ ).

#### Discussion

This is the first study to test heated yoga for a moderately clinically depressed population. This unfunded and uncontrolled pilot study utilized an open-label design to determine whether future more rigorous investigation with an RCT was warranted. This study evaluated BY as it is naturally delivered in the community, without modification or adjustment for clinically depressed individuals (of note: this manuscript only included individuals who completed at least one BY class and subsequent assessment visit). Almost 50%

of participants completed the 8-week intervention (attended BY classes through week 8), and nearly 30% attended at least 75% of the prescribed 16 classes over 8 weeks. However, only three participants completed the full dose of the intervention. Overall our findings support the potential for heated yoga to be further evaluated as a potential intervention for depression as it was associated with a reduction in depressive symptoms, with the caveat that acceptability and feasibility require further attention when designing follow-up studies.

Improvements in symptoms were observed in both clinician-rated (HRSD-17) and self-rated (BDI-I) depression scales over the course of the intervention. Significant improvements were also found for secondary outcomes including hopelessness, anxiety, quality of life, and cognitive and physical functioning. Effect sizes were robust for most clinical outcome measures, with  $d_{GLMM}$  values ranging from 0.57 to 1.43. This finding is encouraging, given that previous meta-analyses have suggested effect sizes in the range of 0.3–0.4 for antidepressant medications.<sup>30</sup> More frequent yoga attendance was associated with greater symptom reductions across most outcomes. Despite this apparent dose-response effect, yoga practice frequency was not randomized, and therefore expectation effects cannot be ruled out. It is also possible that



**FIG. 2.** Number of classes attended by study participants over the 8-week intervention. Participants were asked to attend at least two classes per week. BY, Bikram Yoga; wk, week.

individuals with improving depression were better able to maintain frequent attendance. As reviewed in the Introduction section, these findings are consistent with previous literature supporting both nonheated yoga,<sup>4,6</sup> as well as WBH<sup>7</sup> as potential treatments for depression, and also support the limited extant literature of heated yoga's effect on stress.<sup>11,13</sup>

Almost half of the subjects completed the 8-week intervention, and close to a third attended three quarters or more of the prescribed 16 classes over 8 weeks. A meta-analysis of 115 studies ( $N=20,995$ ) of dropout from cognitive behavioral therapy found the average weighted dropout was 15.9% pre-treatment and 26.2% during treatment, with depression having the highest attrition rate.<sup>31</sup> STAR\*D, the largest clinical trial of depression, cited a 26% attrition-rate as a significant issue.<sup>32</sup> However, the percentage of participants who completed primary study endpoints was significantly lower in this study than in two recent studies of nonheated yoga in subjects with MDD or resistant depression at 94% and 85%, respectively.<sup>33,34</sup> The retention rate in this study was lower than in the other RCT of heated yoga for mental health symptoms, which was 81%<sup>11</sup>—though, this study did not select for clinically significant depressive symptoms. Despite the acceptability and feasibility challenges presented in the present study—such as those listed in the Results (e.g., worsening of pre-existing condition, time commitment, difficulty adjusting to the practice, adverse reactions to BY)—adherence was sufficient to be associated with an antidepressant effect. In essence, even minimal attendance was potentially beneficial, which may encourage participation by individuals who may be reticent about having to make a substantial time commitment. We are currently following up on these findings in a larger, more rigorous study that will yield new insights into feasibility and maximization of treatment adherence with BY in a similar population (NIH/NCCIH K23 AT0080430A1). The findings from this pilot study informed the design of this next-step study—for example, to enhance feasibility and acceptability participants now receive phone calls from the Principal Investigator (PI) on the nonassessment weeks to assess for safety, depressive symptoms, and answer questions; the hope is that these calls will also increase the accountability and connection to the study.

The mechanism by which BY exerts effects on depression remains speculative. Some MDD patients may have abnormal thermoregulation—that is, increased core body temperature and difficulty regulating temperature through perspiration.<sup>7,9,35</sup> In an RCT on WBH for MDD (core body temperature was increased to 101.3°F), normalization of thermoregulatory functions occurred after one session of WBH.<sup>7</sup> One study suggested that BY increased core body temperature by 1.0°F–1.8°F, with more experienced practitioners demonstrating greater temperature increases.<sup>36</sup> A case study used an ingestible thermometer capsule to measure core body temperature during a BY class and found the maximum core body temperature to be 101.6°F,<sup>36</sup> comparable to the core body temperature in WBH.<sup>7</sup>

### Strengths

This is the first known study to examine the acceptability, feasibility, and associated reductions in depressive symptoms of heated yoga for individuals with clinically significant depression. Outcome measures were conducted with

validated clinician- and self-rated instruments. Tracking of attendance allowed correlation between dose and depressive symptom improvement. BY classes were conducted by certified instructors, and delivered in real-world community studios that permitted a wide range of class options (time/day availability), increasing feasibility and generalizability.

### Limitations

This was a small uncontrolled and unblinded pilot study. Those who did not take a yoga class were excluded from analyses, which likely self-selected for those with more motivation and/or ability to attend this intervention. Expectations for yoga were not collected pre-treatment which is also a limitation. An exit interview was only collected at 3-month follow-up (not at early termination) where attrition made data uninformative. Consistent with the national trend in yoga users, this sample consisted predominantly of white college educated females,<sup>37,38</sup> and this limits generalizability with regard to depressed populations in general.

### Conclusions

To our knowledge, this is the first study to demonstrate heated yoga's association with decreased depressive symptoms in a clinically depressed sample. There were significant overall effects across all outcome variables, including depression symptom severity, hopelessness, anxiety, quality-of-life, and cognitive and physical functioning. Feasibility of yoga as an intervention for depression requires further characterization, based on the lower completion rate observed relative to other yoga studies. Replication of these preliminary findings in an RCT is warranted, in addition to comparative studies of heated versus nonheated forms of yoga and studies exploring core body temperature as a mechanism of change in heated yoga.

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