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The effects of acute yoga on anxiety symptoms in response to a carbon dioxide inhalation task in women

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ABSTRACT

Purpose: We investigated the efficacy of yoga for improving cognitive and physical anxiety symptoms, and its possible respiratory mechanism, in high-anxious women.

Methods: Eighteen participants completed 40 min of guided yoga and a light stretching protocol in a randomized, counterbalanced order.The 7.5%CO_2-inhalation task was administered before, immediately after and 1 h after the experimental conditions.State anxiety and panic were measured before and after each inhalation task.Tidal volume, ventilation and respiratory rate were measured during every 7.5%CO_2-inhalation tasks.

Results: There was no significant 3-way interaction($p > .05$).There was a significant main effect of CO_2-inhalation task on panic and respiratory measures($p < .05$).When collapsed over inhalation task and condition, there was a small reduction in cognitive anxiety from baseline to immediately post and 1 -h post-condition ($p < .05$).

Conclusions: There appears to be an overall effect of general physical activity for attenuating anxiety cognitions irrespective of the physiological changes, indicating possible dissociation between the cognitive and physical symptoms of anxiety among women with anxiety sensitivity.

1. Introduction

The practice of yoga is becoming increasingly popular as an alternative approach for reduction and prevention of anxiety symptoms.[1] As a physical practice, yoga involves stretching, balance and strength movements, in addition to breathing and meditation. In certain yoga styles, such as vinyasa, there is deliberate attention on linking breath to movement to increase awareness and control of breathing and bodily sensations.[2] This is particularly relevant for considering yoga as an approach for anxiety reduction(i.e., anxiolysis), given the evidence that individuals with anxiety are also more likely to have heightened sensitivity to changes in their breathing and other bodily sensations that might be misconstrued.[3]

There is a small body of literature examining the acute effects of yoga on anxiety using controlled experimental designs. Two existing studies [4,5] were conducted under naturalistic settings using convenience samples and reported statistically significant reductions in anxiety post-yoga. The lack of a true control condition and randomization, and risk of significant selection bias in these studies limit the quality and therefore the interpretability of the results. Regarding the chronic anxiolytic effects of yoga, a meta-analytic review[6] of 6 randomized controlled studies reported evidence for small, short-term effects of yoga on anxiety compared with no treatment based on a standardized mean difference (SMD) of -0.43, and larger effects were observed compared with active comparators (SMD = -0.86). Collectively, these findings suggest that yoga might be a feasible, and effective approach for anxiety management, especially among those with clinically meaningful levels of anxiety (e.g., clinical diagnosis of an anxiety disorder).[6] The research supports further studies that investigate the anxiolytic effects of yoga under controlled conditions and ideally using potential physiological correlates of this relationship that may delineate the possible mechanisms of action.

Anxiolytic effects of yoga can be studied under controlled laboratory conditions using biological human models of generalized anxiety and panic, namely the carbon dioxide(CO_2) inhalation task. The CO_2-inhalation task is a well-established, validated protocol for anxiety induction and reliably induces anxiety symptoms as well as panic in both healthy and clinical populations.[7–11] The existing studies investigating the CO_2-inhalation paradigm[12–16] in the context of physical activity manipulations have all administered a single vital-capacity 35% CO_2 inhalation procedure to induce panic disorder symptoms. However, no studies have used a longer (e.g., ~5 min) CO_2-inhalation protocol to assess symptoms of more generalized anxiety for a possible anxiolytic effect. The anxiety-inducing (i.e., anxiogenic) effect of this longer

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stimulus might mimic real-life and more generalized anxiety situations (e.g., trait anxiety and anxiety sensitivity) more accurately, and remains to be investigated.

The CO_2-inhalation task to date has not been used to investigate *change in response over time* to control for possible baseline differences across participants before the task is administered. This can be accomplished by assessing symptom severity before and after the inhalation, therefore making the unit of analysis change in response(i.e., Δanxiety). Similar previous studies examining this anxiolytic effect only administered a single or double CO_2-inhalation challenge immediately after the physical activity stimulus.[12–16] Investigation of whether the anxiolytic effects of the stimulus sustains at later time points(e.g., 1 h post-condition) can help determine the duration of such anxiolytic effects and subsequently help inform future study designs.

This study investigated the immediate and delayed anxiolytic effects of acute (one bout) yoga, compared with an active control condition of light stretching, in response to a 5-minute anxiogenic CO_2-inhalation task. Our target demographic were women, who are significantly more likely to suffer from anxiety symptoms and high anxiety sensitivity (AS), which is defined as the tendency to misconstrue physical sensations/experiences that others judge as a normal response in such a way as to elicit intense feelings of panic and fear.[17] We hypothesized that yoga would significantly attenuate the anxiogenic responses to the CO_2-inhalation task when compared with an active control(e.g., light stretching) condition. We further expected acute attenuations in respiratory rate(RR) and ventilation(VE) and increase in tidal volume(Vt), that would accompany the improvements in self-reported anxiety symptoms.

2. Methods and materials

2.1. Participants

Prospective participants were recruited from the University campus, and the study protocol was initially described via telephone. If interested, potential participants were screened following study inclusion criteria (provided in *Supplemental File 1*), which included good overall health and no contraindications to yoga or physical activity. As our target demographic were women with increased AS, Anxiety Sensitivity Index-3 (ASI-3)[18,19] was used to screen individuals with clinically meaningful AS, which is indicated by a 25 or higher on the ASI-3 scale (i.e., ~1 SD above the population norm).

2.2. Outcome measures

Primary outcome measure of this study was state anxiety symptoms, secondarily physical symptoms of panic, and tertiarily the respiratory outcomes.

2.2.1. State anxiety

Spielberger State Anxiety Inventory(SAI)[20] and the Visual Analog Scale-Anxiety(VAS-A) were used to measure current(i.e., "state") anxiety levels before and after the CO_2-inhalation tasks (i.e., change in response over time). The SAI has good psychometric properties,[20–22] items are rated on a 4-point Likert-type scale (1 = not at all to 4 = very much so), and include both cognitive (e.g., "I am worried") and physical (e.g., "I am tense") symptoms of anxiety. The VAS-A is a 100 mm horizontal line anchored with 0 ("not at all") and 100 ("the most ever") to which respondents are asked to make a vertical line indicating how much anxiety they are experiencing at the time. The VAS-A has been reported to capture acute changes in anxiety in clinical populations.[23]

2.2.2. Panic

Panic symptoms were measured by the Acute Panic Inventory(API)[22] which consists of 17 items that assess physical panic symptoms(e.g., palpitations, rapid or difficulty breathing, or sweating) using a 4-point Likert scale(0 = not present to 3 = severe). The API has sound psychometric properties[22] and is commonly used in studies involving the CO_2-inhalation task.[24]

2.2.3. Respiratory outcomes

Tidal volume (Vt), respiratory rate(RR), and ventilation(VE) were assessed as 30-second interval averages of the entire inhalation period (i.e., 5 min of inhalation). We also recorded the peak values reached during the inhalation task, which corresponded with the 5th minute of the inhalation task. Expired air during the CO_2-inhalation task (details of the procedure provided in *Supplemental File 2*) was collected via a computer-based ventilatory expired gas analysis system (TrueOne 2400, ParvoMedics, Sandy, UT).

2.3. Manipulation checks

Heart Rate (HR) and Ratings of Perceived Exertion (RPE) were measured during the yoga and stretching sessions to determine the intensity of the sessions, and served as manipulation checks for distinguishing the intensity of the yoga against the control protocol.

2.4. Procedures and experimental sessions

The procedures were approved by the University Institutional Review Board and written informed consent was obtained from all participants. Participants completed 3 (i.e., 1 baseline and 2 experimental) visits to the research laboratory, each separated by one week. Fig. 1 shows the timeline of experimental study visit procedures. Participants received a remuneration of $10 for the baseline visit and $20 for each experimental session.

2.4.1. Task validation

We a priori validated the efficacy of our CO_2-inhalation task by first validating the duration (i.e., 5 min) for inducing statistically significant levels of self-reported anxiety and panic symptoms in a pilot study (results not published) using a separate, smaller sample. Given that the inhalation task occurs at 3 time points in a single session to allow for assessment of *change in response over time*; we established a time period that permits this type of a repeated-measures design while minimizing significant habituation to the task. We therefore tested and validated a

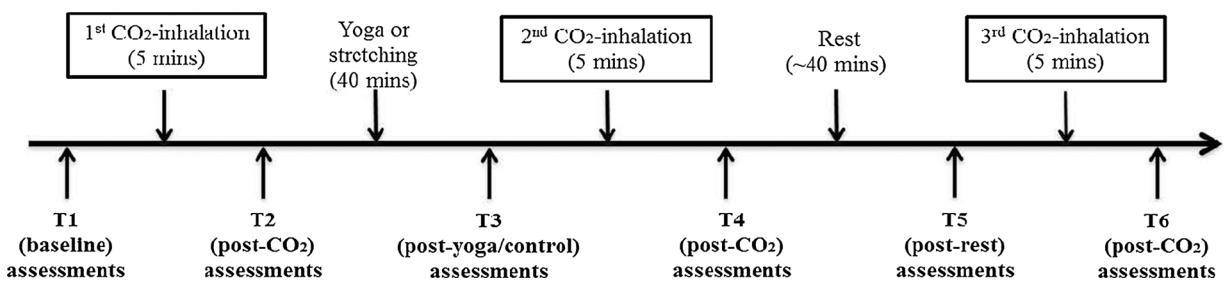

Fig. 1. Timeline of study events.

5-minute protocol as opposed to longer durations that have been reportedly used in various previous studies in the literature. We further picked a 7.5% CO_2 concentration based on similar, previous literature for inducing symptoms of panic and anxiety with successful results(e.g [25]), particularly in individuals with greater generalized anxiety.[26] These collectively provided the bases and the rationale for choosing the specific dose of CO_2-gas mixture in our study.

2.4.2. Baseline assessments

During the baseline visit, participants completed the CO_2-inhalation task twice, with 20 min of resting period in-between. The purpose of repeating the CO_2-inhalation task was twofold: 1)to habituate the participants to the procedure and thus reduce likelihood of a falsely exaggerated anxiety/discomfort response in anticipation of the task (i.e., anticipatory effects) at the subsequent experiment sessions, and 2) to ascertain that the inhalation protocol selected for the study could induce anxiety symptoms(i.e., specificity) repeatedly over time(i.e., reliability).

2.4.3. Experimental conditions

In a within-subjects design with the order of sessions randomized and counterbalanced, participants underwent the CO_2-inhalation task at 3 time points: before(T1), immediately after(T2) and 1 h after(T3) the manipulation (i.e., yoga or stretching control) (See Fig. 1). Participants completed the SAI, VAS-A, and the API while seated in a comfortable chair before and after each inhalation task, for a total of 6 times at each session. The pre-/post-administration of the questionnaires allows for the measurement of *change in response* from pre- to post-inhalation task at each time point and this is a statistically robust method which accounts for *possible between-person variability at pre-inhalation at each time point (i.e., T1, T2, T3)*. The 40-minute yoga/stretching protocol was followed immediately by asking the participants to report peak RPE (i.e., "the highest level of exertion they felt during the session"). After the 2nd inhalation task (with SAI, VAS-A, and the API administrations pre- and post-inhalation), participants were seated in a comfortable chair for ~40 min (to allow for a total of exactly 1 h between the end of the yoga/stretching session and the 3rd inhalation task) for a resting period, during which they were provided with reading material that was screened for any content on physical activity, yoga, anxiety, or panic. This was followed by the 3rd CO_2-inhalation task, with final SAI, VAS-A, and the API administrations pre- and post-inhalation.

2.4.3.1. Yoga protocol. The complete list and order of the yoga poses are provided in Supplemental Table 1. The yoga sequence for the study was designed based on published recommendations on how to design and implement yoga protocols for research purposes.[2] In Vinyasa flow yoga, the practitioner moves from one pose to the next, synchronized with an inhalation or exhalation, at a faster pace than in other styles such as Hatha yoga.[27] The 40 min duration was selected so that several rounds of sun salutations and common sequences could fit into the session, which is typical in community-based vinyasa flow style yoga classes, to achieve an acute, ecologically valid manipulation. Participants mirrored the yoga instructor (an exercise physiologist with 4 years of instructing stretching and yoga classes in research studies), who instructed and guided the participants throughout the sequence.

2.4.3.2. Control protocol. The complete list and order of the stretching exercises are provided in Supplemental Table 2. In the control condition, participants completed a "stretching" protocol of minimal movement for 40 min. Participants were guided through light stretching (e.g., body twists, leg/hamstring stretches, arm and shoulder stretches) while seated or lying down on a mat. These control sessions were also led/guided by the instructor. The stretching poses have been previously used in exercise training studies in our research laboratory with other populations (e.g., adults with multiple sclerosis), and controls for social contact and attention from the instructor. This type of active control condition is considered to be ecologically valid and appropriate for studies of acute physical activity and mood, as it accounts for the social aspect of the intervention, as well as the passage of time and its potential transient effect on mood.[28]

2.5. Data analysis

Data were analyzed in SPSS v. 22.0. Separate 2(condition) × 3 (assessment time point) × 2(pre- and post-inhalation task) repeated-measures analyses of variance(ANOVAs) were conducted for each self-reported outcome measure (i.e., API, SAI, VAS-A) to identify the interactions and main effects of condition(yoga and control) and assessment time point(pre-, immediately post-, 1 -h post-condition) from before to after inhalation task. To provide a comprehensive profile of the physiological fluctuations during this task, respiratory data(i.e., Vt, RR, and VE) were analyzed using two different approaches: (a)by taking the 30-second averages of the entire 5-minute inhalation task period (results provided in Table 5); and (b)by taking the peak values reached for each measure, which corresponded with the final minute of inhalation task. Partial eta squared(η_p^2) statistic was computed for all scores reported in the ANOVAs and the suggested norms of 0.01(small), 0.06(medium), and .14(large) were used to assess the magnitude of the size of the effect size (ES).[29]

2.5.1. Post hoc analyses

We conducted a mixed-effects regression analysis to assess the within- and between-subjects variation in responses over time. Each outcome (i.e., API, SAI, and VAS-A scores) was separately regressed on the 3 time points (coded as Δ ($_{\text{Post-inhalation-Pre-inhalation}}$)) and a dummy-coded variable representing the condition comparisons (i.e., 1 = Yoga, 2 = Control). To account for the random effect of time and fixed effect of condition, change at 3 times points and condition were entered as covariates into the model, which yielded estimates of the average within-person slope (change in panic, and change in state anxiety), and the addition of time as a random effect yielded the variance in the estimate of the within-person slopes. To account for person-level differences in habitual physical activity levels, we conducted the same mixed-effects regression models with the total GLTEQ scores added as a fixed-effect (i.e., trait measure). This yielded the moderating effects of trait-condition interactions on change on panic and anxiety symptoms.

3. Results

3.1. Study recruitment and enrollment

Ninety-three women initially contacted our laboratory via email or phone expressing interest in in the study. Forty-six of them expressed further interest and were screened. Twenty-four individuals met the criteria for inclusion, 2 individuals decided not to continue due to the required time commitment for the study and therefore 22 participants were scheduled for testing. Three participants were not able to complete the full 5 min of breathing of the 7.5% CO_2-air mixture during the baseline session and therefore disqualified. One participant dropped out after the 1st experimental session because of time-commitment issues. Ultimately, 18 participants completed all 3 visits and constitute the final sample size for the data analyses.

3.2. Participants

Sample characteristics are provided in Table 1. The mean score on the ASI was 32.2 (*SD* = 6), which is ~2 *SDs* above the normative value (i.e., M = 19) for the general adult population. The sample further had clinically meaningful levels of generalized (i.e., "trait") anxiety symptoms, measured by the Spielberger Trait Anxiety Inventory(TAI),[20]and

Table 1
Descriptive characteristics for the study sample ($N = 18$). *SD* = Standard deviation.

Variable	Mean (*SD*)
Age (years)	22.1 (5.0)
Height (cm)	166.2 (4.9)
Weight (kg)	64.9 (11.4)
HADS-Anxiety	9.8 (4.7)
HADS-Depression	5.2 (3.9)
TAI (i.e., trait anxiety) score	46.4 (10.3)

the anxiety subscale of the Hospital Anxiety Depression Scale HADS.[30] The mean score on the TAI was 46.4(*SD* = 10.3), which is ~1.4 *SD* above the mean population normative score of 34.8(SD = 9.2) reported for adult women (Spielberger et al., 1983). The mean HADS anxiety score was 9.8(SD = 4.7) and the mean HADS depression score was 5.2(SD = 3.9), indicating clinically meaningful anxiety without depression, based on the established cut-off score of 7.[31]

3.3. Change in state anxiety

The 3-way interaction between condition (i.e., yoga, control), assessment time point(i.e., T1, T2, T3) and inhalation task (i.e., pre- vs post-inhalation task) on SAI or VAS-A scores was not significant($p > .05$)(See Table 3). However, there was a significant 2-way interaction between assessment time point and inhalation task($p < .05$) for the VAS-A, indicating that the effect of inhalation task varied across assessment time points(See Table 3). There was a slight increase(Δ) from pre- to post-inhalation from T1 to T3(i.e., Δ values of ~15, ~17 and ~21 for T1, T2 and T3, respectively). Furthermore, the main effects of assessment time point and inhalation task were statistically significant ($p_s < .001$)(See Table 5). Similarly, SAI scores increased from pre- to post-inhalation task independent of condition or assessment time point (Table 2), based on the significant main effects of assessment time point and inhalation task($p < .001$). When collapsed over inhalation task and condition, the scores were significantly different at each assessment point(i.e., T1 = 32.25, T2 = 27.03 and T3 = 30.50), based on the significant main effect of time.

3.4. Change in panic

There was a statistically significant main effect of inhalation task ($p < .001$), indicating that the CO_2-inhalation task reliably induced symptoms of panic independent of condition and assessment time point (see Table 3). The 3-way and 2-way interaction effects were not statistically significant.

3.5. Change in respiratory response

There was a significant main effect of assessment time point for all variables, indicating that the respiratory responses differed across the 3 time points independent of condition (See Tables 4 and 5).

3.6. Manipulation checks

HR and RPE. The mean HR was 90(*SD* = 19.3) b·min^{-1} and 78(*SD* = 14.9) b·min^{-1} during the yoga and control sessions, respectively, though the difference was not statistically significant. Mean RPE was 12(*SD* = 1.8) and 9.8(*SD* = 2.6) for the yoga and the control sessions, respectively. These values suggest that participants were working at a light-to-moderate intensity during the yoga condition and at a very light intensity during the control condition. Paired samples *t*-tests comparing peak RPE values reported for yoga and control session indicated a statistically significant difference between the 2 conditions[$t(17) = 5.18$, $p < .001$]. Accordingly, the intensity of the yoga session approached moderate intensity based only on the RPE value.

Table 2
Mean scores (*SD*) on the self-report measures to the 1st, 2nd (i.e., immediately post-condition) and 3rd (i.e., 1 h post-condition) inhalation tasks during the experimental (i.e., yoga) and control (i.e., stretching) sessions. API = Acute Panic Inventory, SAI = State Anxiety Inventory, VAS-A = Visual Analog Anxiety Scale.

Time point	API				SAI			
	Yoga		Control		Yoga		Control	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1st inhalation task	1.00 (1.33)	8.39 (4.67)	1.06 (1.55)	8.89 (5.17)	31.55 (8.58)	43.06 (12.11)	32.94 (10.31)	43.17 (10.72)
2nd inhalation task	1.17 (2.20)	8.50 (5.87)	.72 (1.41)	6.89 (2.87)	26.83 (6.04)	39.67 (12.00)	27.22 (8.82)	40.06 (10.94)
3rd inhalation task	.83 (1.29)	8.67 (6.13)	.67 (.97)	7.61 (5.98)	29.17 (9.88)	42.17 (12.55)	31.83 (9.16)	41.11 (13.48)

Time point	VAS-A			
	Yoga		Control	
	Pre	Post	Pre	Post
1st inhalation task	13.67 (12.43)	28.83 (21.60)	17.83 (13.76)	32.94 (22.10)
2nd inhalation task	6.72 (7.27)	24.00 (21.65)	8.17 (10.11)	24.39 (19.34)
3rd inhalation task	7.67 (9.25)	27.22 (22.17)	6.78 (7.10)	29.11 (24.85)

3.7. Effect of CO2-inhalation task

The mean scores(± *SD*) for the SAI, VAS-A, and API before and after the inhalation task at each time point for yoga and control conditions (Table 2) demonstrate a reliable change in anxiety symptoms with the CO_2 challenge.

Table 3
ANOVA results for the Acute Panic Inventory (API), State Anxiety Inventory (SAI), and the Visual Analog Anxiety Scale (VAS-A) scores. Condition (yoga, control), Time point (Baseline, immediately post yoga/control, 1 h post yoga/control), inhalation task.

API	*df*	*F*	η_p^2	*p*
Condition	1	1.49	.08	
Time point	2	1.31	.07	
Inhalation task	1	55.53	.77	< .001
Condition*time point	2	1.27	.07	
Condition* Inhalation task	1	.88	.05	
Time point* Inhalation task	2	.64	.04	
Condition*time point* Inhalation task	2	1.25	.07	
SAI	*df*	*F*	η_p^2	*p*
Condition	1	.32	.02	
Time point	2	9.63	.36	< .001
Inhalation task	1	40.08	.70	< .001
Condition*time point	2	.52	.00	
Condition* Inhalation task	1	1.09	.06	
Time point* Inhalation task	2	.88	.05	
Condition*time point* Inhalation task	2	1.06	.06	
VAS-A	*df*	*F*	η_p^2	*p*
Condition	1	.94	.05	
Time point	2	14.31	.46	< .001
Inhalation task	1	21.52	.56	< .001
Condition*time point	2	1.84	.10	
Condition* Inhalation task	1	.06	.00	
Time point* Inhalation task	2	3.58	.17	< .05
Condition*time point* Inhalation task	2	.35	.02	

Table 4
Mean peak values (*SD*) during the 5th minute of inhalation for respiratory measures in response to the 1st, 2nd and 3rd inhalation tasks during the experimental (i.e., yoga) and control (i.e., stretching) sessions. RR = Respiratory Rate, VE = Ventilation, Vt = Tidal volume. All values are the *peak* values reached during the 5th minute of the CO_2-inhalation task.

Time point	RR		Vt (liters)		VE (liters/min)	
	Yoga	Control	Yoga	Control	Yoga	Control
1st inhalation task	29.11 (6.46)	28.89 (4.79)	1.74 (.35)	1.72 (.33)	47.26 (12.81)	46.21 (12.12)
2nd inhalation task	28.61 (7.73)	27.50 (4.74)	1.76 (.33)	1.76 (.32)	47.08 (13.55)	45.76 (12.49)
3rd inhalation task	28.72 (7.66)	28.28 (5.80)	1.77 (.32)	1.74 (.30)	47.74 (14.07)	47.15 (12.54)

Table 5
ANOVA results for respiratory rate (RR), tidal volume (Vt), and ventilation (VE). Condition (yoga, control), assessment time point (Baseline, immediately post-condition, 1 h post-condition), minute of inhalation task (1-minute averages over the course of the entire 5-minute inhalation task).

RR	*df*	*F*	η_p^2	*p*
Condition	1	.46	.03	
Time point	2	2.56	.15	
Inhalation task	9	59.67	.80	< .001
Condition*time point	2	.50	.03	
Condition* Inhalation task	9	.88	.05	
Time point* Inhalation task	18	1.12	.07	
Condition*time point* Inhalation task	18	.60	.04	
Vt	*df*	*F*	η_p^2	*p*
Condition	1	1.11	.07	
Time point	2	1.57	.10	
Inhalation task	9	164.2	.92	< .001
Condition*time point	2	.03	.00	
Condition* Inhalation task	9	.94	.06	
Time point* Inhalation task	18	1.00	.06	
Condition*time point* Inhalation task	18	1.36	.08	
VE	*df*	*F*	η_p^2	*p*
Condition	1	1.38	.08	
Time point	2	1.13	.07	
Inhalation task	9	123.2	.89	< .001
Condition*time point	2	1.34	.08	
Condition* Inhalation task	9	.51	.03	
Time point* Inhalation task	18	1.49	.09	
Condition*time point* Inhalation task	18	1.44	.09	

3.8. Post hoc analyses

The results of the mixed-effects regression models did not differ significantly from those of the primary data analysis (See Supplemental Table 3). Of note, there was statistically significant heterogeneity in the variance of the estimate for the effect of time, suggesting while there was an overall attenuation in response to the CO_2 inhalation task, this time effect varied across participants.

4. Discussion

The goal of this study was to investigate the immediate and delayed anxiolytic effects of a single session of guided yoga in response to a 5-minute anxiety-inducing CO_2-inhalation task in a sample of women with high AS. Our main hypothesis was not supported in that the yoga condition did not induce a larger attenuation in anxiety symptoms compared to the control condition. However, there was an attenuation in self-reported anxiety symptoms over time independent of condition and inhalation task, which was not paralleled by the pattern of physical panic or respiratory outcomes, indicating a disassociation of cognitive symptoms of anxiety from its physiological correlates. To our knowledge, this is the first study to include both self-reported and objective (i.e., respiratory) measures of anxiety and panic in a sample of women with elevated AS to assess whether there is agreement between self-reported versus physiological aspects of anxiety following an acute session of yoga. In this regard, our study goes beyond those existing in the literature that included convenience samples by including not only an active control and within-subjects randomization, but also physiological measures that might be associated with the anxiolytic effects of yoga.

The main effects for the anxiety scores point to an overall effect of physical activity on the cognitive symptoms of anxiety. Looking at the main effect of time point; the mean VAS-A scores for each of the 3 assessment time points were T1 = 23.32(*SD* = 14.91), T2 = 15.82 (*SD* = 12.22) and T3 = 17.69(*SD* = 13.66), suggesting a decline in anxiety symptoms from baseline to subsequent time points. Further, the ESs(i.e., Cohen's *d*) from T1 to T2 and T1 to T3 were 0.55 and 0.39, respectively. These ESs are larger in magnitude than what has been reported by prior meta-analyses (e.g., Hedge's *g* = .16 by Ensari et al., 2015; Cohen's *d* = .24 by Petruzzello et al., 1991). Similarly, when collapsed over condition and inhalation task, there was an attenuation in the change in SAI scores from baseline to subsequent time points, indicating that the effect was independent of condition and irrespective of physical and physiological symptoms of anxiety.

In terms of physiological correlates, there was a significant main effect of inhalation task on respiratory outcomes (See Table 5). Specifically, RR and VE increased over the course of the inhalation task, and this increase was consistent across the 3 time points and 2 conditions (See Table 4). This finding indicates that physiological changes parallel the self-reported physical symptoms but not the cognitive symptoms of anxiety, in response to the anxiogenic stimulus. Our observations collectively from the physiological and self-reported measures suggest that the acute cognitive improvements after a bout of yoga or stretching activities might be independent of the possibly inherent and centrally-mediated physiological responses to the CO_2-inhalation task.[32] Alternatively, these individuals might be better able to effect changes in their perceived anxiety, as compared to the physiological changes, that may or may not occur later during recovery, or later in their learning process(i.e., over many more sessions of yoga).

Respiratory responses in our sample were similar to others published in previous studies(e.g [33,34]). For example, Schaefer et al.[33] showed that "high ventilators", when compared to "low ventilators" (determined based on severity of panic symptoms in response to a 7.5% CO_2-inhalation task), reacted with much greater RR but lower Vt within the first 5 min of the inhalation task. The range of RR among these high ventilators was between 20 and 30(means not reported), compared to a range of 27.5–29.1 in our sample. Similarly, Papp et al.[35] reported a mean RR of 23 and Vt of ~1.6 l during the first 5 min of a 7% CO_2-inhalation task, which is closer to ours(i.e., 1.6–1.7 L). These findings collectively provide further evidence for the typical respiratory response observed in sensitive individuals (i.e., "responders" or "high ventilators"). Given that the self-reported anxiety symptoms reduced over time in our study, it might be possible that the cognitive responses to the CO_2-inhalation protocol might be independent of physiological responses in individuals with heightened anxiety sensitivity.[32]

There are some limitations in our study. First, we had a relatively small(i.e., *N* = 18) sample size, and the effect sizes(i.e., η_p^2) for interaction and main effects were small-to-moderate in magnitude. Next, though the control condition in this study design was selected to control for attention and social interaction, future studies might consider using a meditation-only control condition as an alternative to the light stretching protocol we administered. Finally, we did not conduct a comparison of individuals with high vs low AS, as our target demographic was individuals with heightened AS and greater risk for generalized anxiety. Such a comparison might be another future direction to determine if the observed effects are specific to the high AS group, or more generally, to women.

5. Conclusion

In conclusion, our findings do not support our primary hypothesis and suggest that both vinyasa style yoga and light stretching activities might induce similar effects of general physical activity for acute anxiolysis. However, our assessment of whether self-reported anxiety patterns follow physiological patterns associated to anxiety following an acute session of yoga indicate a disassociation of cognitive symptoms of anxiety from its physiological correlates.

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Declaration of Competing Interest

All authors declare no potential conflict of interest related to the data collection for the study and the preparation of this manuscript. Parts of this study were completed in partial fulfillment of the first author's doctoral degree.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.ctim.2019.102230.

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