



Mitigating Rural Adolescent Trauma: Remote Delivery of a Trauma-Informed Yoga Intervention During COVID-19

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Abstract

Given the prevalence of childhood trauma in rural Montana, this project is intended to help mitigate stressors that may contribute to poor behavioral and mental health in high school-aged children, which may be exacerbated by the collective trauma of the COVID-19 pandemic. The immediate goal was to measure physical and mental health outcomes in adolescents resulting from a remotely delivered trauma-informed yoga intervention designed to foster positive youth development. Our study builds on the successes from an initial feasibility pilot study one year prior in order to evaluate a more robust intervention comparing experimental and control group outcomes. Students at a small, rural high school in Montana volunteered to participate in a 6-week, twice-weekly trauma-informed yoga intervention in their physical education class. Validated survey measures, including the PHQ-A, GAD-7, and ACE-Q instruments, were utilized to measure mental health outcomes pre- vs. post-intervention. Salivary cortisol levels were also measured pre-, mid-, and post-intervention. Statistically significant declines in cortisol levels and improvements in sleep duration were noted when comparing experimental vs. control groups. Noteworthy declines in depression and anxiety levels were also seen when comparing the treatment to control groups. Descriptive differences between the control and experimental groups illustrate the mental health benefits of reduced anxiety and depressive symptoms in rural adolescents resulting from a remotely delivered trauma-informed yoga intervention. Our study holds the potential for a long-term public health impact in reducing adolescent rates of anxiety and depression while mitigating trauma in geographically isolated settings.

Trial Registration: ClinicalTrials.gov identifier: NCT04664855.

Keywords Adolescents · Trauma · Depression · Anxiety · Yoga · COVID-19

Introduction

“...it is easier to build strong children than repair broken men.” (Frederick Douglass)

It is no secret that adolescence can be one of the most emotionally difficult phases in one's life, even in the best of times; adding the collective trauma of a global pandemic compounds these challenges. Recent evidence indicates that mental health crises are on the rise for both adolescents and adults, and an early study indicates that increases in

adolescent depression and anxiety may be linked to the coronavirus pandemic (Chatterjee, 2021; Courtney et al., 2020; Lee, 2020). Further, school scheduling changes, like remote learning, shatter routines necessary for students, which are especially crucial coping mechanisms for those with mental health conditions (Lee, 2020). This study sought to mitigate these, and other mental health difficulties, through a novel, remotely delivered trauma-informed yoga intervention to rural high school students in Montana during the COVID-19 pandemic.

Significance

Given the prevalence of suicide and mental health issues in rural Montana (Montana Department of Health and Human Services, 2016), which will be elucidated below, this efficacy study was designed to help mitigate the impact of

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contributing factors by providing coping strategies through breathing techniques and somatic experiencing for rural high school adolescents; these coping strategies have been linked to improvements in overall mental health and behavioral outcomes, which may ultimately lead to reduced suicide rates (Khalsa et al., 2012a). Our study builds on the successes from an initial feasibility pilot study one year prior (Authors, manuscript in preparation) in order to evaluate a more robust intervention comparing experimental and control group outcomes. Ultimately, this project aimed to promote positive youth development and student success in school-aged children concurrently with providing rural access to novel interventions during a worldwide pandemic crisis. Further, it aligns with multi-tiered systems of support (MTSS) conceptual frameworks that are currently implemented in most public schools nationally (including the district involved in this study) and provides a tiered support system for students in a trauma-informed educational setting (Dorado, 2020).

Context: Rural Montana and the Mental Health Crisis

The Rocky Mountain region is frequently referred to as the nation's "suicide belt;" both empirical evidence, as well as observed behaviors and anecdotes, point to high altitude, lower oxygen levels, and prolonged cold and darkness in the winter as possible contributing factors (Shukitt-Hale & Lieberman, 1996; Siegler, 2018). Recent findings from the Centers for Disease Control and Prevention (2020) indicate that Montana consistently ranks in the top 5 states with highest suicide rates in the nation. The town in which this study took place typically exceeds three times the national average in suicide rates and, unfortunately, these often involve youth suicides (KULR 8, 2013).

Adolescent Mental Health in Montana

A 2010–2014 longitudinal study showed that 39.1% of Montana adolescents aged 12–17 sought treatment for a major depressive episode (Montana Department of Health and Human Services, 2016). Depression likely contributes to Montana's high rate of youth (ages 11–17) suicides, which, as a state as whole, more than double the U.S. youth suicide rates; 74% of those suicides presented with warning signs (American Foundation for Suicide Prevention, 2017). In the county in which this study took place, the 2019 Youth Risk Behavior Survey indicated that 39% of high schoolers experienced severe depression, 20% made a suicide plan, and 16% attempted suicide (Montana Office of Public Instruction, 2019). Tragically, one high school suicide took place (of a student not involved in the study) during the study implementation period.

Barriers to Mental Health Care

Geographic challenges unique to this area due to rugged terrain lead to significant barriers to receiving many services; germane to this study, accessing mental health care services is exceedingly difficult in the rural mountain west, but especially in Montana (Kaiser Family Foundation, 2016). As nearly half of the state is classified as rural or frontier, rural Montana has a starkly deficient quantity of mental health care providers to meet rural community members' mental health care needs and faces lengthy travel distances and poor travel conditions to reach quality providers (National Network of Libraries of Medicine, 2020; National Center for Frontier Communities, 2018). While this study is unique to the state of Montana, similar geographic barriers and access to care difficulties exist nationally amongst other rural locales. Thus, new treatment and prevention delivery modalities are needed to increase access to evidence-based mental health treatments for rural citizens—especially by intervening adolescents in the school setting.

Indication for a Trauma-Informed Intervention

In children, specific traumas are considered an "adverse childhood experience," or an "ACE;" the seminal study by Felitti et al. (1998) categorize ten forms of trauma into emotional, physical, and household challenges and link these experiences to a myriad of mental and physical health complications in adulthood. In addition to these primary traumas, the coronavirus pandemic is also considered to be a collective stressor, which can cause resulting (and potentially collective) traumatic events (Kaysen, 2021). Further, Porges (2020), recently highlighted the need for the mitigation of trauma during and following the coronavirus pandemic with his assertion that "We are a traumatized species.... [and] trauma will be the second pandemic."

COVID-19 has challenged our perceptions of safety, which is a necessity for a regulated autonomic nervous system (and key for handling stressors and traumatic events); Porges postulates that feelings of safety not only promotes mental and physical health but quarantining and isolation limited opportunities to co-regulate with others, which is especially true for children who have been unable to attend school during the pandemic (2020). While it is true that not everyone has the same genetic vulnerability toward maladaptation from stressors, trauma can shift the autonomic nervous state, disrupting neurophysiological regulation (such as sleep, digestion, etc.) (Heim & Teicher,

2020; Porges, 2020). Additionally, this shift caused by stressors in the autonomic nervous system can release hormones, including the corticotropin releasing factor (CRF), which triggers the release of cortisol, a stress hormone; the release of CRF can cause a permanent upregulation of the autonomic nervous system, which can lead to autoimmune diseases, depression, stress, and anxiety (Heim & Teicher, 2020).

This dysregulation of the nervous system, caused by stressors and trauma, underscores the need for a new paradigm of treatment of trauma focusing on the autonomic state as the intervening variable (Porges, 2020). The intervention employed in this study, trauma-informed yoga, utilizes physical sequences and breathing strategies that have proven useful in mediating physiological trauma responses, including regulating the nervous system (Cook-Cottone et al., 2017).

Intervention Design and Framework: Trauma-Informed Yoga

Yoga has been proven to benefit individuals' mental and physical health consistently; studies on yoga has indicated its use as a therapeutic intervention nearly 50 times in the last 15 years, reporting positive mental health outcomes in measures of resilience, anger, anxiety, stress, depression and fatigue as well as physical health improvements such as flexibility, strength, and weight loss (Khalsa et al., 2012b). For youth, yoga can be particularly beneficial in improving cortisol levels, stress, anxiety, depression, academic performance, and sleep (Davis & Buchanan, 2020a, b; Butzer et al., 2015; Cook-Cottone et al., 2017; Emerson & Hopper, 2011). Due to high rates of adverse childhood experiences in the county in which this study was completed (of over 20% of its adults reporting having an ACE score of 4 or more), a trauma-informed yoga intervention is indicated; in alignment with trauma-informed multi-tiered systems of support frameworks (MTSS), this intervention addresses Tier 1 (80% of the student population) by providing strategies for coping with stress for students (Dorado, 2020; Montana Office of Public Instruction, 2019; PRC Custom Research, 2020).

A trauma-informed yoga session differs from traditional yoga practice. A trauma-informed yoga instructor can make intentional, trauma-informed choices regarding avoidance of certain props, like use of straps, which may emulate

restraints that could trigger the yoga practitioners or avoiding certain poses that could be triggering in positionality (Emerson & Hopper, 2011). It is also prudent for the trauma-informed yoga instructor to educate the participants on how yoga can help heal the dysregulated stress response/nervous system for their own understanding of the practice (Emerson & Hopper, 2011; Cook-Cottone et al., 2017).

As referenced earlier, empirical evidence supports that trauma-informed yoga can calm the nervous system; rhythmic, self-soothing somatosensory input (which is fostered in a yoga practice) leads to physical senses of safety (which is key in healing trauma) and pleasure, leading to the release of "pleasure" hormones and regulation of stress-related neural systems (Malchiodi & Perry, 2020; Porges, 2020). Further, an indicator of autonomic nervous system health, yoga has proven improvements in heart rate variability in trauma survivors (van der Kolk, 2014).

Additionally, trauma can cause difficulties in perceiving one's physical body and personal boundaries; the loss of the "somatic sense of self" has led to those who have experienced trauma as sharing comments like "I feel detached from my body" and "I feel like my body does not belong to me" as well as experiencing physical symptoms like rapid heart rate, shortness of breath, and pain (Lanius et al., 2020). These sensations result in a condition known as alexithymia, which is difficulty in identifying one's feelings and distinguishing between those feelings and bodily sensations from emotional arousal (and communicating these feelings with words) (Lanius, 2021). Moreover, trauma may impact "peri-personal space" in that traumatized individuals will frequently misperceive how far away objects and other people are due to a lack of spatial awareness (Rabellino, 2021). Yoga, which focuses on both interoception (understanding one's own interior landscape) and proprioception (understanding one's relationship to others in an environment), can help individuals regain their sense of physical space (Malchiodi & Perry, 2020).

To regain this somatic sense of self and heal one's trauma, trauma experts assert that a traumatized individual must regain a sense of embodiment by integrating interoceptive and exteroceptive sensations, which leads to the "agentive embodied self" (Rabellino, 2021). Trauma-informed yoga works to reintegrate these sensations through intentional teaching of mindfulness practices, stress reduction, and an embodied practice, as illustrated by Table 1 below and

Table 1 Conceptual Framework for Trauma-Informed Yoga Intervention (Cook-Cottone et al., 2017)

Symptoms Related to Trauma Exposure	Elements of YIS-TIY
Hyperarousal and Dissociation	Embodied Practice (Physicality and Interoceptive Awareness)
Avoidance and Re-experiencing	Engagement in the Present Moment (Yoga and Mindfulness Practices)
Alterations in Cognitions	Intentional, Empowered Thinking (12 Cognitive Intentions)
Relational Disconnection	Yoga Teacher Presence and Responsiveness (Relational Attunement)

utilized as the conceptual framework for this study (Cook-Cottone et al., 2017). This conceptual framework was adapted for use for our 6 week program, as shown in Fig. 1 below.

Implications for School-Based Mental Health Initiatives.

ACEs not only impact one's adult health outcomes, but they also cause multiple mental health and academic complications during youth. Brackett (2019) asserts the following:

One in five American children is experiencing a mental health issue, such as depression or anxiety, and over half of all seventeen-year-olds report having either experienced trauma directly, ranging from neglect to abuse, or witnessed it at least once as a child. By failing to recognize trauma's effects on learning, educators risk compounding the trauma and jeopardizing students' prospects in school.... depending on our emotional state, our chemical and hormonal profiles change dramatically, and our brains function differently. The three most important aspects of learning--attention, focus, and memory--are all controlled by our emotions, not by cognition (p. 192; p. 195).

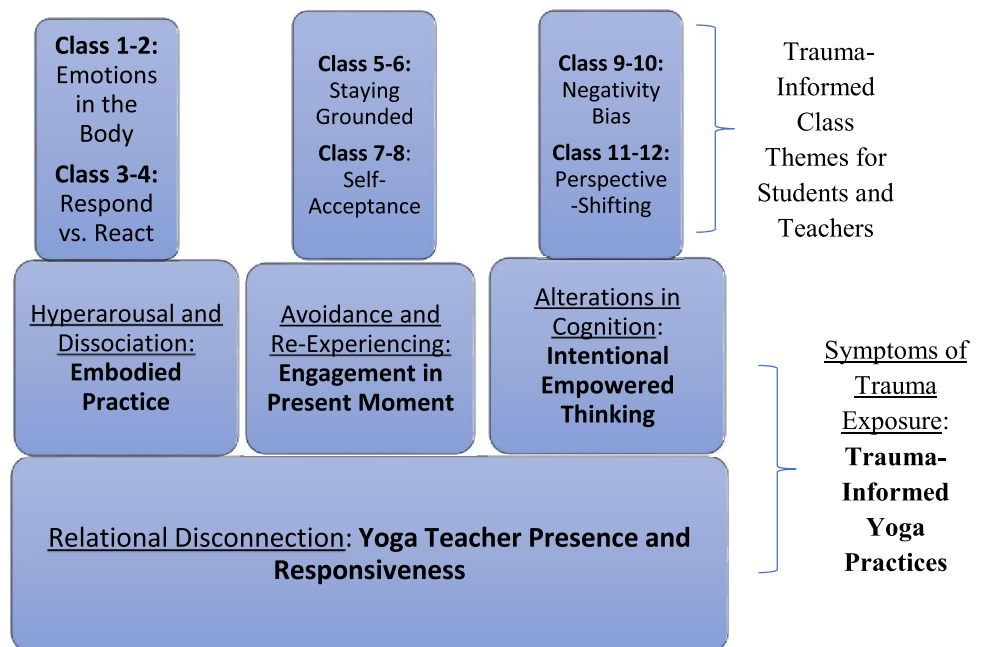
Because most ACEs tend to originate from the household and/or caregivers, schools become the low-hanging fruit as a logical setting for providing widespread support for traumatized youth. Brackett further posits that by "failing to recognize trauma's effects on learning, educators risk compounding the trauma and jeopardizing students' prospects in school" (2019, p. 192). Porges (2020) also notes that trauma disrupts primary learning functions, including but

not limited to: difficulties in listening, following verbal commands, and speech-language delays, prosody, and behavioral regulation. Moreover, The Aspen Institute's National Commission on Social, Emotional, & Academic Development also argues that the promotion of social, emotional, and academic learning is "the substance of education itself" (2019, p. 6). Therefore, a school-based intervention is indicated in the alleviation of childhood trauma.

Theoretical Framework: Community-Based Participatory Research

To successfully integrate a school-based intervention into the curriculum, as well as understand the environment and demographics of the study, the research team must be embedded within the context; therefore, a community-based participatory research framework (CBPR) is necessary in carrying out this important work. Israel et al. (2001) define community-based participatory research as "focusing on social, structural, and physical environmental inequities through active involvement of community members, organizational representatives, and researchers in all aspects of the research process" (p. 182). A community advisory board (CAB) had already been established in previous iterations of the research to represent key community and school stakeholders impacted by the project. For this study, the principal investigator strengthened the existing school-community-academic partnership through strategic involvement in multiple community action and school district committees, including a community-focused suicide prevention and resilience steering committee, a school district-focused

Fig. 1 Conceptual Framework for Trauma-Informed Yoga Intervention (adapted from Cook-Cottone et al., 2017)



“Suicide, Intervention, and Refer to Treatment” steering committee, and CAB meetings. Informal feedback from the CAB was gathered at the conclusion of the previous study and throughout the implementation of this study to continuously assess local relevance, collaborative engagement, disseminate results, and make programmatic adjustments for future studies.

Research Aims

As a limited feasibility and efficacy study for a remotely delivered, rural intervention, our study had two primary objectives:

Aim 1: Pilot test a limited feasibility and efficacy study of a remotely delivered (via Zoom) trauma-informed yoga intervention for 15–18 year-old male and female high school students.

To prepare for this study, feedback was gathered from the school district, teachers, and students via focus groups and email communications to assess the burden from the various assessment instruments and participation in the pilot. Assessment measures listed later in this manuscript comport with this feedback. Retention and satisfaction of participants, as measured by survey instrumentation from the previous iteration of the research indicated the need for an ongoing partnership with the school district and an expansion to additional high school physical education classes for a 6-week intervention while also including a new control group. The intervention’s efficacy for youth mental and physical health was assessed with validated surveys measuring depressive and anxiety symptomology, as well as resilience, and cortisol testing to measure physiological changes. Participants were given Fitbit Inspire HR wearable fitness trackers as both an incentive and as an additional physiological measure; however, participant engagement with fitness trackers (both in wearing

and syncing devices) was inconsistent at best and thus, data from these trackers were not included as a measure in this study.

Participation rates and assessment outcomes were considered to determine feasibility for future remotely delivered interventions as well as to explore scalability to rural communities without access to yoga instructors while providing a safe, socially-distanced contingency for COVID-19 school closures and schedule changes.

Aim 2: Evaluate the study’s school-community-academic partnership at the conclusion of the program using a qualitative survey.

The results were compared with data from the same survey, collected at the end of the previous year’s study. The PI shared results from these surveys, along with study outcomes, with the CAB to determine areas for program refinement and assess the need for a study continuation and expansion within the district.

Methods

Sample

Forty-five students at a small, rural high school in Montana volunteered to participate in this study. The analytical sample includes 23 students who completed both the pre and post measures in the treatment group and 22 students who completed the same assets in the control group. The majority of participants identified as white ($n=41$) and male ($n=25$ males). The number of sessions attended ranged between three and twelve, with a median of nine sessions. The majority of students (47.8%) attended at least 10 sessions and 1 student attended every session. Among our sample, 23.5% of our participants had a moderate ACE score at the onset of the study (an ACE score of 2–3), while 38.2% had a high ACE score (of 4 or more ACEs). Descriptive statistics for the full sample on the outcome measures are provided in Table 2.

Table 2 Summary Statistics on Outcome Measures

Variable	Overall ($n=45$) Mean (SD)	Control ($n=22$) Mean (SD)	Percent Change Control Group	Treatment ($n=23$) Mean (SD)	Percent Change Treatment Group
Pre-GAD7	6.07 (5.19)	5.27 (5.13)		6.83 (5.25)	
Post-GAD7	4.96 (5.28)	4.55 (4.54)	-13.66%	5.35 (5.97)	-21.67%
Pre-PHQ	6.71 (6.00)	5.36 (4.89)		8.00 (6.75)	
Post-PHQ	5.31 (6.09)	4.18 (5.24)	-22.01%	6.39 (6.73)	-20.13%
Pre-CDRISC	6.82 (7.35)	28.32 (7.11)		25.39 (7.45)	
Post-CDRISC	27.60 (8.66)	30.45 (6.44)	7.52%	24.87 (9.71)	2.05%
Pre- Cortisol	0.53 (0.40)	0.71 (0.44)		0.30 (0.19)	
Post- Cortisol	0.36 (0.25)	0.49 (0.27)	-30.99%	0.22 (0.12)	-26.67%

Measures

Adverse Childhood Experiences

The Center for Youth Wellness ACE-Q Teen self-report is a 19-item survey that is broken into two subscales; the first subscale measures traditional adverse childhood experiences (on a scale of 0–10) while the second quantifies events that are hypothesized to be correlated to a dysregulated stress response on a scale of 0–9 (i.e., toxic stress caused by discrimination, bullying, unsafe housing, etc.) (Bucci et al., 2015). For the purposes of this study, only the first subscale for adverse childhood experiences was utilized in calculating ACE scores; other circumstances perpetuating toxic stress (i.e., bullying, homelessness, food insecurity, etc.) were excluded. ACE scores pre intervention ranged from 0 to 10 with a mean of 3.09 and a standard deviation of 2.95 and post mean of 2.22 with a standard deviation of 2.51. Thirty-eight percent of students were categorized as having a low ACE score (a score of 0–1), 23.5% had a moderate ACE score (a score of 2–3), and 38.2% were categorized as having a high ACE score (a score of 4–10).

Adolescent Anxiety

The Generalized Anxiety Disorder Scale (GAD-7) (Spitzer et al., 2006) is a 7-item practical self-report anxiety questionnaire where participants are asked how often, during the last 2 weeks, they have been bothered by each of the 7 core symptoms of generalized anxiety disorder. Response options are "not at all," "several days," "more than half the days," and "nearly every day," scored as 0, 1, 2, and 3 respectively. Therefore, GAD-7 scores range from 0 to 21, with scores of > 5, > 10, and > 15 representing mild, moderate, and severe anxiety symptom levels. In this study, the GAD-7 demonstrated high internal consistency (Cronbach's alpha of 0.90) for the sample in this study. The GAD-7 has also shown strong reliability (0.85) and validity (73.3%) in prior research (Rutter & Brown, 2017).

Adolescent Depressive Symptoms

The Patient Health Questionnaire for Depressive Symptomatology for Adolescents (PHQ-A) (Johnson, 2002) is a self-report 9-item instrument to assess symptoms of depression among adolescents at study onset. Participants were asked to indicate how often they have been bothered by eight possible problems or symptoms over the last 2 weeks (e.g., "feeling down, depressed, or hopeless," "feeling tired or having little energy," and "feeling bad about yourself, or that you are a failure, or have let yourself or your family down"). Each item was rated 0 (not at all), 1 (several days), 2 (more than half the days), or 3 (nearly every day), and items were summed

to obtain scale scores. Internal consistency for this scale was high (Cronbach's alpha = 0.90) in the sample. The PHQ-A has also demonstrated strong reliability (0.875) (Bian et al., 2011).

Resilience

The Connor-Davidson Resilience Scale (CD-RISC) (Connor & Davidson, 2003) is a self-report 10-item instrument to assess one's perceptions of self-resilience and agency. Each question is scored on a Likert scale of 0 to 4, where 0 indicates "not at all," 1 indicates "rarely true," 2 indicates "sometimes true," and 4 indicates "true nearly all the time." Scores can thus range from 0–40, with higher scores indicating higher resilience. Scores are broken into four quartiles; scores from 0–29 exemplify a low resilience score, 30–32 is low-intermediate resilience, 33–36 is high intermediate resilience, and a score of 37–40 exemplifies high resilience. Internal consistency for this study's scale was high with a Cronbach's alpha of 0.90 in the sample. The 10-item CD-RISC measure has also shown adequate internal reliability (0.85) in other studies (Gonzales et al., 2016).

Below is a table of the various survey measures, and their corresponding validity and reliability, utilized in this study; additionally, all students were all screened pre- and post-intervention by the Columbia Suicidality Screener, per the school district's request, but these results were not included in the findings from this study Table 3.

Intervention Design

District leaders wished to hold the study during the Jan-March 2021 window, as this timeframe has shown a historical spike in inappropriate student behaviors and absenteeism. This study aimed to have at least 30 students in each group (control and experimental); while the project initially had a sufficient sample size for statistical significance ($n > 30$ in each group), due to attrition, COVID-19 quarantining students, and other difficulties beyond the research team's control, the final data set included 23 students in the treatment group and 22 in the control group. Students in both groups were from three different physical education classes taught by the same physical education teacher; the experimental group was composed solely of freshmen students, and the control group was a variety of sophomore, junior, and senior students. Students in the experimental group were asked to provide qualitative feedback after each yoga session (according to prompts provided by the yoga instructors) as well as at the conclusion of the study to provide overall feedback regarding their perceptions of the intervention.

During the 2020–2021 academic year, the high school involved in this study was administered in an A/B Cohort model; that is, students were split in half into two separate

Table 3 Assessment Measures

Description of Measure	Source	Timeline for Dissemination	Cronbach's Alpha/Validity & Reliability from Prior Research
Center for Youth Wellness ACE-Q Self-Reporting Screener for Teens	Bucci et al., 2015	Pre-intervention (in order to determine ACE scores of participants)	Longitudinal testing currently underway to measure content and construct validity/reliability
Generalized Anxiety Disorder Scale (GAD-7)	Spitzer et al., 2006	Pre- and post-intervention	Cronbach's alpha: .79-.91 Reliability = .85 Validity = 73.3%
Patient Health Questionnaire for Depressive Symptomology for Adolescents (PHQ-A)	Johnson, 2002	Pre- and post-intervention	Chronbach's alpha = .835 Reliability = .875 Validity = 89.5%
Connor-Davidson Resilience Scale (CD-RISC)	Connor & Davidson, 2003	Pre- and post-intervention	Reliability = .85

groups (A and B). Students in Cohort A attended school face-to-face twice weekly while students in Cohort B attended school remotely from home while Cohort A students were in school, and the reverse happened for Cohort B students to attend school while Cohort A students worked from home. To test the remote delivery of this intervention, sessions were held for each cohort during their regularly scheduled physical education class time while they worked remotely from home; this not only protected the physical education teacher's in-person instructional time for each cohort, but it also promoted healthy activity and wellness for students as they learned from home. Students in the control group did not receive any yoga during the intervention, but they were provided with recordings from the intervention sessions after the study's conclusion. Sessions for the experimental group were twice weekly for six weeks for each cohort, and each session lasted 45 min via Zoom and were led by two certified trauma-informed yoga instructors; one benefit to remote delivery was that it created the opportunity for instructors outside of rural Montana to be a part of the yoga instruction. Thus, one instructor taught virtually from within the rural Montana community, and the other instructor taught remotely from Madison, Wisconsin.

Considerations for the remote delivery of this intervention primarily revolved around student safety. Given that trauma-informed yoga can bring up strong emotions (related to previous adverse experiences), as well as potential physical injury, students had brief "check-ins" with the instructors at the beginning of each session. At the conclusion of each session, yoga instructors provided journaling prompts, via the Zoom Chat feature, to help participants process and reflect upon how the session impacted their physical and mental states. Participants entered these journal entries into a confidential Google Form survey, which was then reviewed by the researchers and yoga instructors. Wraparound support services were offered to participants who reported any kinds of difficulties resulting from the class, whether physical or emotional. Students who shared physical difficulties were

given modifications for following classes by the instructors, and those who reported emotional distress were referred to school-based therapists and counselors. Any student with mental health/safety concerns were also immediately referred to school administration, who then initiated a parent/guardian contact for student safety.

Analytical Methods

Because these classes were pulled from the same physical education teacher, this allowed for computer-generated randomization. Instead of individuals being randomly assigned, gym class clusters of individuals were randomly allocated to intervention groups. This approach is necessary because randomization at the individual level is impractical and we sought to avoid contamination between treatment groups.

For all participants, baseline surveys (see Table 2 below), were conducted prior to exposure to Yoga (T0). Follow-up surveys were collected at 6 weeks (T1). Analyses were conducted using R Version 3.6. Baseline differences between intervention and control group were examined using independent *t* test or χ^2 test. All data was analyzed according to the treatment assignment.

Cortisol Analysis

Students in both the experimental and control groups were administered salivary cortisol testing at the beginning of weeks 1 and 3 and the conclusion of week 6, each time on an "in-person" day at school, prior to their physical education class. Specifically, students provided a saliva sample to PI, which was deidentified (using a code key system) before analysis by the Center for American Indian and Rural Health Equity's Translational Biomarkers Core Lab at Montana State University. Testing used the Abcam (ab154996) cortisol in vitro competitive ELISA (Enzyme-Linked Immunosorbent Assay) kit designed for accurate quantitative measurement of cortisol in saliva (sensitivity

0.12 ng/ml). Deidentified cortisol data was returned to the PI for re-identification using the code key, and comparisons using paired *t* tests assessed trends to determine usefulness of this measure.

Quantitative Results

Analyses

The study investigated the impact of participating in yoga on various outcomes among a sample of 45 high school students randomly assigned to either a treatment ($n = 23$) or control group ($n = 22$). Of the 45 students, 25 were male and 20 were female. Randomization eliminates selection bias definitionally, leaving a role only to chance differences. This reduces the plausibility of other threats to internal validity. Because groups were randomly formed, any initial group differences in maturational rates, in the experience of simultaneous historical events, and in regression artifacts, ought to be due to chance.

For all three outcomes, the first regression model, or the unadjusted model, included the treatment group variable only. The second model adjusted for baseline levels of the measures, and the third and final regression model includes gender as a covariate. The data were analyzed as a treatment on the treated, as surveys were only completed by participants. Additionally, dosage effects were measured by the number of sessions attended. The number of sessions attended ranged between three and twelve, with a median of nine sessions. The dose was examined as a predictor variable added to the third model, but there were no significant relationships detected between attendance and the outcome measures (depression, anxiety, or resilience). We further investigated if there were interactions between baseline scores on measures and treatment group; based on our limited statistical power, no interaction was significant.

Model 1 $Y_{\text{Post}} = \beta_0 + \beta_1 \text{Treatment}$.

Model 2: $Y_{\text{Post}} = \beta_0 + \beta_1 \text{Treatment} + \beta_2 \text{Pre}$.

Model 3: $Y_{\text{Post}} + \beta_1 \text{Treatment} + \beta_2 \text{Pre} + \beta_3 \text{Gender}$.

Based on the summary statistics earlier in Table 2, the treatment group saw a greater decline in anxiety versus the control group (21.67% vs. 13.66%). The decline in depression was similar between the two groups (20.13% vs. 22.01%). Interestingly, the control group had a greater increase in resilience than the treatment group. However, there were no significant differences in any measure between the groups.

Further, a sensitivity analysis was also conducted to assess the dose–response relationship between number of treatments received and post-study outcomes. Using dosage, or number of sessions as the outcome, as opposed to the treatment dummy of treatment versus control, did not result in different results for anxiety, depression, or resilience. Again, we did not detect statistical significance. Additionally, no significant differences were observed between males and females in any of the study outcomes. Our null findings may reflect the fact that we had low power due to small sample sizes, resulting in a reduced probability of rejecting the null hypothesis when it is indeed false. Implications and possible reasons explaining this will be discussed in the Discussion Section; tables illustrating these outcomes are provided below Tables 4, 5, 6, 7 and 8.

Cortisol Analysis

Although descriptive statistics indicated a greater downward trend in PHQ-A and GAD-7 scores for the treatment group, we did not detect significant differences in depression, anxiety, or resilience among students who received the yoga treatment in comparison to the control group. However, a significant difference in cortisol level was observed between students assigned to the treatment and control group. Students in the treatment group had significantly lower cortisol levels at post-intervention; this finding remained significant when controlling for differences in baseline cortisol levels. No significant differences were observed between males and females in cortisol levels.

A sensitivity analysis was then conducted to assess the dose–response relationship between number of treatments

Table 4 Model Results for GAD-7 (Anxiety)

GAD-7	Model 1			Model 2			Model 3		
	Est	SE	95% Conf Int	Est	SE	95% Conf Int	Est	SE	95% Conf Int
Intercept	4.546***	1.135	[2.256, 6.834]	0.271	0.869	[-1.482, 2.024]	0.314	0.872	[-1.446, 2.074]
Treatment	0.802	1.588	[-2.399, 4.004]	-0.457	0.995	[-2.464, 1.550]	-1.010	1.162	[-3.356, 1.337]
Baseline				0.811***	0.097	[0.615, 1.006]	0.760***	0.111	[0.535, 0.985]
Gender (Male as ref)							1.228	1.328	[-1.455, 3.911]
Adj. R ²	-0.017			0.610			0.609		

The Cohen's *d* effect size for the treatment is -0.19 and represents the average intervention effect on the treated

* indicates $p < .05$; ** indicates $p < .01$; *** indicates $p < .001$

Table 5 Model Results for PHQ-A (Depression)

PHQ-A	Model 1			Model 2			Model 3		
	Est	SE	95% Conf Int	Est	SE	95% Conf Int	Est	SE	95% Conf Int
Intercept	4.182**	1.290	[1.580, 6.784]	-0.271	0.909	[-2.105, 1.563]	-0.273	0.915	[-2.121, 1.575]
Treatment	2.209	1.805	[-1.431, 5.849]	0.021	1.094	[-2.187, 2.229]	-0.378	1.256	[-2.915, 2.158]
Baseline				0.830***	0.092	[0.644, 1.016]	0.799***	0.104	[0.588, 1.009]
Gender (Male as ref)							0.939	1.419	[-1.926, 3.803]
Adj. R ²	0.011			0.655			0.650		

The Cohen's *d* effect size for the treatment is -0.06 and represents the average intervention effect on the treated

* indicates $p < .05$.; ** indicates $p < .01$.; *** indicates $p < .001$

Table 6 Model Results for CD-RISC (Resilience)

CD-RISC	Model 1			Model 2			Model 3		
	Est	SE	95% Conf Int	Est	SE	95% Conf Int	Est	SE	95% Conf Int
Intercept	30.455***	1.765	[26.896, 34.013]	9.765*	4.043	[1.605, 17.924]	8.575	4.378	[-0.265, 17.416]
Treatment	-5.585*	2.468	[-10.563, -0.607]	-3.447	1.953	[-7.388, 0.495]	-4.248	2.248	[-8.788, 0.292]
Baseline				0.731***	0.134	[0.459, 1.002]	0.762***	0.142	[0.476, 1.047]
Gender (Male as ref)							1.736	2.368	[-3.047, 6.518]
Adj. R ²	0.086			0.451			0.445		

The Cohen's *d* effect size for the treatment is -0.49 and represents the average intervention effect on the treated

* indicates $p < .05$.; ** indicates $p < .01$.; *** indicates $p < .001$

Table 7 Association Between Number of Treatments Received and Pre- and Post-Intervention: GAD-7

GAD7	Model 1			Model 2			Model 3		
	Est	SE	95% Conf Int	Est	SE	95% Conf Int	Est	SE	95% Conf Int
Intercept	4.684***	1.103	[2.459, 6.909]	0.165	0.871	[-1.593, 1.923]	0.205	0.877	[-1.565, 1.976]
Treatment Count	0.061	0.171	[-0.285, 0.406]	-0.022	0.107	[-0.237, 0.193]	-0.073	0.126	[-0.326, 0.181]
Baseline				0.806***	0.096	[0.611, 1.000]	0.760***	0.113	[0.532, 0.989]
Gender (Male as ref)							1.041	1.342	[-1.670, 3.751]
Adj. R ²	-0.020			0.608			0.605		

* indicates $p < .05$.; ** indicates $p < .01$.; *** indicates $p < .001$

Table 8 Association Between Number of Treatments Received Pre- and Post-Intervention: PHQ-A

PHQ-A	Model 1			Model 2			Model 3		
	Est	SE	95% Conf Int	Est	SE	95% Conf Int	Est	SE	95% Conf Int
Intercept	4.544***	1.263	[1.998, 7.090]	-0.445	0.918	[-2.298, 1.408]	-0.433	0.927	[-2.306, 1.440]
Treatment Count	0.172	0.196	[-0.2241, 0.567]	0.047	0.115	[-0.186, 0.280]	0.017	0.136	[-0.257, 0.290]
Baseline				0.826***	0.090	[0.644, 1.009]	0.802***	0.106	[0.589, 1.016]
Gender (Male as ref)							0.643	1.447	[-2.280, 3.566]
Adj. R ²	-0.005			0.656			0.649		

* indicates $p < .05$.; ** indicates $p < .01$.; *** indicates $p < .001$

Table 9 Model Results for Cortisol Levels

CORTISOL (ug/dl)	Model 1			Model 2			Model 3		
	Est	SE	95% Conf Int	Est	SE	95% Conf Int	Est	SE	95% Conf Int
Intercept	0.492***	0.044	[0.407, 0.577]	0.319***	0.073	[0.177, 0.462]	0.333***	0.070	[0.196, 0.470]
Treatment	-0.271***	0.062	[-0.392, -0.151]	-0.167*	0.070	[-0.303, -0.030]	-0.263**	0.084	[-0.428, -0.099]
Baseline				0.246**	0.085	[0.078, 0.413]	0.199*	0.085	[0.032, 0.367]
Gender (Male as ref)							0.142	0.074	[-0.004, 0.287]
Adj. R ²	0.290			0.377			0.412		

The Cohen's *d* effect size for the treatment is 1.30 and represents the average intervention effect on the treated

* indicates $p < .05$; ** indicates $p < .01$; *** indicates $p < .001$

Table 10 Association Between Number of Treatments Received Pre- and Post-Intervention: Cortisol Levels

CORTISOL (ug/dl)	Model 1			Model 2			Model 3		
	Est	SE	95% Conf Int	Est	SE	95% Conf Int	Est	SE	95% Conf Int
Intercept	0.472***	0.044	[0.386, 0.559]	0.306***	0.071	[0.166, 0.446]	0.315***	0.069	[0.180, 0.450]
Treatment Count	-0.026***	0.007	[-0.040, -0.013]	-0.016*	0.007	[-0.030, -0.002]	-0.025**	0.009	[-0.042, -0.008]
Baseline				0.257**	0.085	[0.090, 0.424]	0.217*	0.085	[0.050, 0.383]
Gender (Male as ref)							0.132	0.075	[-0.015, 0.279]
Adj. R ²	0.232			0.367			0.396		

* indicates $p < .05$; ** indicates $p < .01$; *** indicates $p < .001$

Table 11 Mean Cortisol Levels among Males and Females at Pre-, Mid-, and Post-Intervention

Cortisol Levels	Females	Males	p-value ^a
	Mean (SD)	Mean (SD)	
Cortisol- Time 1	0.51 (0.50)	0.54 (0.33)	0.83
Cortisol- Time 2	0.43 (0.29)	0.49 (0.29)	0.52
Cortisol- Time 3	0.33 (0.28)	0.38 (0.23)	0.54
Change in Cortisol (Time 3—Time 1)	-0.12 (0.42)	-0.16 (0.28)	0.69

^aP-values derived from pooled T-Test

received and post-study cortisol levels. An unadjusted association was observed between the number of treatments and post-study cortisol levels, with an average cortisol reduction of 0.026 ug/dl for every additional treatment received by participants ($p < 0.001$). This association remained when

controlling for baseline cortisol levels, with a 0.016 ug/dl reduction in cortisol, on average per treatment (< 0.01), and average reduction of 0.025 ug/dl ($p < 0.01$) when controlling for baseline cortisol levels and gender. In sum, there was a statistically significant association based upon the number of sessions completed; the more sessions a participant engaged in, the greater the reduction in cortisol levels Tables 9, 10, 11 and 12.

Additionally, a sleep analysis was performed to determine whether the yoga intervention had any impacts on participants' self-reported sleep quality and duration; no significant linear association was observed between sleep duration (n hours) and cortisol level. However, when expressed as a binary variable (less than 8 h vs. 8 or more hours), a significant difference in means was observed ($p = 0.05$), with a mean cortisol level of 0.49 ug/dl among those sleeping less than 8 h compared to 0.38 ug/dl among those sleeping 8 or more hours. When comparing mean cortisol levels according

Table 12 Linear Association between Number of Treatments Received and Change in Cortisol Levels between Pre- and Post-Intervention Period

Predictor Variable	Geometric Mean	95% Confidence Interval	p-value
Per each additional treatment received	<i>Unadjusted</i> ¹		
	0.01	(-0.01, 0.04)	0.17
	<i>Adjusted for baseline cortisol levels</i> ²		
	-0.02	(-0.03, -0.01)	0.03
	<i>Adjusted for baseline cortisol levels and gender</i> ³		
	-0.03	(-0.04, -0.01)	<0.01

Table 13 Linear Association between Sleep Duration and Cortisol Levels

Predictor Variable	Geometric Mean	95% Confidence Interval	p-value
Hours Slept	-0.01	(-0.05, 0.02)	0.44

Table 14 Difference in Cortisol Levels by Sleep Quality and Duration

Variable	Mean Cortisol Level	SD	N	p-value
<i>Perceived quality of prior night's sleep</i>				
Didn't sleep well	0.48	0.31	48	0.18
Slept well	0.4	0.32	76	
<i>Sleep Duration</i>				
Less than 8 h	0.49	0.37	81	0.05
8 or more hours	0.38	0.23	48	

to self-reported sleep quality, no statistically significant difference was observed between those who “slept well” and those who “did not sleep well” the prior night ($p=0.18$). Additionally, no association was observed between number of treatments and sleep duration, and no association was observed between number of treatments and perceived sleep quality (comparing those who slept well to those who didn't sleep well) (as evidenced by a linear regression to model the association between number of treatments and hours of sleep and a logistic regression to model the odds of sleeping well for every additional treatment received) Tables 13, 14, 15 and 16.

Discussion

While the study indicates descriptively that the intervention of trauma-informed yoga was beneficial to experimental group participants (when comparing outcomes to the control group), insufficient sample sizes limited our statistical power to detect significance. Furthermore, it is highly

likely that the external stressors caused by the pandemic may have artificially deflated post-intervention survey outcomes and/or underestimated improvements. During the six week intervention period, multiple traumatic events occurred within the local and school community that directly impacted all participants in this study; as mentioned earlier, one high school student (not involved in this study) took their life (and many of the experimental group participants knew and/or were friends with this student). Another crisis related to school/student safety occurred mid-intervention period which led to a two-day school closure, heavy police activity, and evacuation of some students from their homes. Therefore, both the safety concerns that could have caused excessive stress and/or trauma responses in participants—as well as the need for a trauma-informed intervention in this sample—are important to highlight here. Further research is needed to explore possible differences in resilience levels between the control and treatment groups (i.e., age may be a factor, etc.).

Additionally, the research team has concerns regarding potential survey bias for students who indicated suicidal ideation on the Columbia Suicidality Screener, which was not included in the results of this study but was requested to be completed by the school district. These students, per medical/suicide intervention guidance, were pulled the same day of the pre-survey to assess immediate risk by the school nurse to assess imminent risk to their one safety (and determine a potential need for referral to mental health services); this action, however, may have influenced those students to *not* answer in such a way that they would be “called out” (or parents notified) on their PHQ-A post-surveys, which also included a question on suicidal ideation.

Study Limitations

As alluded to previously, there were limitations to this study, both in design and also extenuating circumstances related to COVID-19. While the research team hoped to have enough of a sample size to analyze statistical significance, due to attrition rates and participants quarantined for COVID-19 exposure and/

Table 15 Association between Number of Treatments Received and Post-Intervention Sleep Duration

Model 1	Model 2			Model 3					
	Est	SE	95% Conf Int	Est	SE	95% Conf Int	Est	SE	95% Conf Int
Hours Slept									
Intercept	7.762***	0.329	[7.117, 8.406]	3.938**	1.218	[1.551, 6.325]	4.166**	1.303	[1.613, 6.720]
Treatment Count	-0.039	0.051	[-0.138, 0.061]	-0.003	0.044	[-0.090, 0.083]	0.01	0.052	[-0.092, 0.112]
Baseline				0.514**	0.157	[0.206, 0.821]	0.489**	0.165	[0.166, 0.811]
Gender (Male as ref)							-0.258	0.534	[-1.304, 0.788]
Adj. R ²				0.172			0.155		

* indicates $p < .05$.; ** indicates $p < .01$.; *** indicates $p < .001$

Table 16 Association between Number of Treatments Received and Post-Intervention Sleep Quality

	Model 1				Model 2				Model 3			
	Est	SE	Odds Ratio	95% Conf Int	Est	SE	Odds Ratio	95% Conf Int	Est	SE	Odds Ratio	95% Conf Int
Sleep Quality												
Intercept	0.865	0.479			-3.135	2.262			-3.504	2.497		
Number of Treatments	-0.013	0.071	0.987	[.859, 1.134]	0.028	0.079	1.029	[.882, 1.200]	0.189	0.141	1.208	[.917, 1.593]
Baseline					0.545	0.302	1.724	[.953, 3.116]	0.483	0.326	1.62	[.856, 3.066]
Gender (Male as ref)									-1.044	0.649	0.124	[.010, 1.580]
AIC	55.94				51.808				50.618			

* indicates $p < .05$.; ** indicates $p < .01$.; *** indicates $p < .001$

or infection, our sample size had limited power to detect statistical significance, although descriptives indicate the strong potential of this intervention. Additionally, this sample was ethnically homogenous (all but four students were white); further research needs to explore this intervention with a more diverse group of participants, both in age and ethnicity. Attendance for the intervention also was inconsistent among several participants, which inevitably impacted study results, but also makes our findings more conservative; poor school attendance and engagement are often related to the incidence of adverse childhood experiences (Blodgett & Lanigan, 2018).

Moreover, regarding the intervention itself, the research team was unable to secure a single yoga teacher for every session of the intervention, so two teachers were used each week of the intervention, which introduces the possibility of variability of results based on different teachers' styles. While this research study also intended to utilize additional, reliable physiological data with sleep from wearable fitness trackers worn by all participants across both groups, participant engagement with the devices was inconsistent at best. Many participants did not wear their devices regularly, nor did they sync them at the requested intervals (and several lost the device altogether); therefore, self-reports of sleep quality and duration used in this study may be considered less reliable than what could have potentially been gathered from these wearable health devices.

Finally, it is worth noting that self-reporting by adolescents is inherently less reliable than physiological data. For example, when asked on a qualitative, open-ended survey how "stressed out" students felt about COVID-19, most students replied that they "were not stressed" about the pandemic; however, physiological evidence suggests the inverse is true. While baseline levels of cortisol were much lower in the experimental group compared to the control group, (baseline level = 0.31 ug/dl in the experimental group and 0.71 ug/dl in the control group), a normal/healthy range is 0.10–0.20 ug/dl, so the participants all had notably high baseline cortisol levels. This indicates a potential mismatch in how students perceive their own anxiety levels compared to their actual physiological response to stress.

The research team postulates that, among other possibilities, there are two distinct ones that rise above the others to explain this misalignment. First, as mentioned above, this community suffered multiple crises not only during the intervention period, but also during the entire course of the pandemic; one theory is that students' positioning on the hierarchy of needs (in terms of immediate survival and safety) may have superseded those of the threat of COVID-19 (Maslow, 1970). An additional possibility relates to alexithymia, which is often attributed to trauma survivors. As mentioned earlier in this manuscript, alexithymia is defined as difficulty in identifying one's feelings and communicating these feelings with words; this leads to the distinct possibility that the students' self-reports were inaccurate (as

compared to the physiological findings) because they were incapable of identifying their own feelings and/or describing them on the survey, thus leading to further potential survey bias (Lanius, 2021).

Conclusions and Implications

Given the prevalence of suicide and mental health issues in rural Montana, and especially in the community in which this study took place, this project was intended to help mitigate stressors that may contribute to poor behavioral and mental health in high school-aged children, which may be exacerbated by the collective trauma of the COVID-19 pandemic. Twenty percent of American adolescents experience mental health difficulties, and over 50% of all seventeen-year-olds have reported experiencing some form of trauma (Brackett, 2019). Further, “anxiety disorders are the most common mental illness in the U.S., affecting 25% of children between 13 and 18 years old...[and] Depression is the leading cause of disability worldwide” (Brackett, 2019, p. 3). Despite limitations of statistical power (based on insufficient sample sizes in each group) to indicate significance in self-reported survey measures in this study, the descriptive differences between the control and experimental groups illustrate the mental health benefits of reduced anxiety and depressive symptoms in rural adolescents resulting from a remotely delivered trauma-informed yoga intervention.

Physiologically, statistically significant differences of post-intervention cortisol levels between the control and treatment groups exemplify the promise of this intervention in the reduction of stress hormone levels. Further exploration and research are needed to include a larger and more diverse sample to determine generalizability to both rural and urban contexts; however, our study holds the potential for a long-term public health impact in reducing adolescent rates of anxiety and depression while improving stress-related physical health and mitigating trauma in geographically isolated settings.

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Data Availability Due to the nature of this research, participants of this study did not agree for their data to be shared publicly, so supporting data are not available.

Declarations

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Consent to Participate Parent Consent/Student Assent was obtained for all study participants. This study involving

human participants was in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standard and was approved by the Institutional Review Board at Montana State University.

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