Calm College: Testing a brief mobile app meditation intervention among stressed college students

by

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ABSTRACT

College students experience a considerable amount of stress. Unmanaged stress is associated with poor academic performance, health risk behaviors (i.e., inadequate sleep and physical activity, alcohol consumption, poor dietary behaviors), and poor mental health. Coping with stress has become a priority among universities. The most tested stress-related programs to date have been mindfulness-based and face-to-face. These programs demonstrated significant improvements in stress, mindfulness, and self-compassion among college students. However, they may be burdensome to students as studies report low attendance and low compliance due to class conflicts or not enough time. Few interventions have used more advanced technologies (i.e., mobile apps) as a mode of delivery. The purpose of this study is to report adherence to a consumer-based mindfulness meditation mobile application (i.e., Calm) and test its effects on stress, mindfulness, and self-compassion in college students. We will also explore what the relationship is between mindfulness and health behaviors.

College students were recruited using fliers on college campus and social media. Eligible participants were randomized to one of two groups: (1) Intervention - meditate using Calm, 10 min/day for eight weeks and (2) Control – no participation in mindfulness practices (received the Calm application after 12-weeks). Stress, mindfulness, and self-compassion and health behaviors (i.e., sleep disturbance, alcohol consumption, physical activity, fruit and vegetable consumption) were measured using self-report. Outcomes were measured at baseline and week eight.

Of the 109 students that enrolled in the study, 41 intervention and 47 control participants were included in analysis. Weekly meditation participation averaged 38 minutes with 54% of participants completing at least half (i.e., 30 minutes) of meditations. Significant changes between groups were found in stress, mindfulness, and self-compassion (all $P<0.001$) in favor of the intervention group. A significant negative association ($p<.001$) was found between total mindfulness and sleep disturbance.

An eight-week consumer-based mindfulness meditation mobile application (i.e., Calm) was effective in reducing stress, improving mindfulness and self-compassion among undergraduate college students. Mobile applications may be a feasible, effective, and less burdensome way to reduce stress in college students.

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LIST OF DEFINITIONS

Stress - Stress is described as a feeling of being overwhelmed or any uncomfortable emotional experience that exceeds the person's coping ability.[1, 2]

Mindfulness - Bishop et al proposes a two-concept model for mindfulness, self-regulation of attention and orientation to experience. Self-regulation of attention involves skills such as: sustained attention, attention switching, and the inhibition of elaborative processing. Orientation to experience means having a "beginner's mindset" (i.e., curiosity, openness, acceptance) with each new moment that arises.[3]

Self-compassion - Neff describes self-compassion as being understanding and caring towards oneself, understanding that humans are imperfect and make mistakes, and involves being aware of one's present moment in a clear and balanced way.[4]

Meditation- Edenfield and Saeed describes meditation as intentional and self-regulated attention for the purpose of relaxing and calming the mind and body.[5]There are two main classes of meditation practice: concentration meditation (e.g., transcendental meditation) and mindfulness meditation (i.e., awareness or insight meditation). Transcendental meditation involves the restriction of attention to a single point or object. Mindfulness meditation is the practice of maintaining steady attention on a constantly changing field of objects.[6]

Mindfulness-Based Stress Reduction (MBSR)- MBSR was developed by Dr. Jon Kabat-Zinn designed to manage mental health and chronic pain patients who were non-responsive to conventional treatment. MBSR is an 8-wk program with each session including mindfulness practice and education on applying mindfulness to everyday

situations and life.[7] Each session is typically 2.5 hours in length with a single all-day training. Daily homework is given, which primarily consists of meditation practice, mindful yoga, applying mindfulness to everyday life, and occasional worksheets (e.g., pleasant events calendar).

Mindfulness-Based Cognitive Therapy (MBCT)- MBCT is based on both CBT for depression and MBSR components. Unlike CBT, there is little emphasis on changing the content of thoughts, but rather on changing awareness and relationship to thoughts.[8] MBCT is an 8-wk group based skills-training program that helps develop recognition and disengagement from habitual patterns especially rumination. The program also included daily homework. The daily homework included either guided (e.g., prerecorded meditations) or unguided awareness exercises (i.e., application of training in everyday life).[8]

INTRODUCTION

It is well established that stress is a major contributor to psychosocial and physical health.[9, 10]College students experience a considerable amount of stress and challenges to their well-being.[11] This age group often reports higher levels of stress than any other generation with many college students being unable to cope exacerbating their distress by ruminating or placing judgement on themselves resulting in both an emotional and physical impact.[12-15] The college experience offers a unique set of stressors and demands, such as (1) moving away from home, (2) leaving family and friend support systems, (3) learning to manage finances (4) learning to balance an increased academic workload, extracurricular activities (5) and manage their emotional reactions to both success and disappointment.[11, 16] These events inherent to the college experience contribute to the high levels of reported stress. Studies suggest up to 86% of college students report feeling overwhelmed by all they have to do, naming stress (32.2%), anxiety (24.9%), and sleep difficulties (20.6%) as the top three factors impacting their academic performance.[17]

Unmanaged elevated stress in college students is often associated with impaired academic performance, poor health behavior choices, and anxiety and depression.[18, 19] Poor health behaviors include smoking, alcohol consumption, other drug use, lower physical activity levels, less consumption of fruits and vegetables, and higher consumption of pop and junk food.[9, 20, 21] These negative health behaviors, contribute to additional stress and physical (e.g., obesity, metabolic disorders, hypertension) and mental (e.g., anxiety and depression) disorders. In fact, most mental health disorders arise in young adulthood with 75% of young adults having the first onset by the age of 25.[22, 23]

Stress, when coupled with anxiety and/or depression is associated with suicidal ideation in college students, the second leading cause of death amongst this age group.[24] A report found that 60.8% of students felt overwhelming anxiety, 38.2% felt so depressed that it was difficult to function, and 10.4% seriously considered suicide.[17] Additionally, approximately 50% of the students who reported continuous mental health issues did not seek mental health treatment.[22] Students that do seek treatment for mental health issues experience long wait times, short term counseling (i.e., an average of 5 sessions), and occasional cost.[25] The prevalence of stress, associated negative health behavior choices and mental health issues as a result of stress, and the limitations to current treatment in the college setting signifies the need for effective stress management strategies for college students.

Implementing effective stress reduction programs on college campuses to help students cope has become a priority for counseling services, wellness programs, and fitness centers across the country.[26, 27] Most universities have stress management programs available to their students[25] such as education, resources (e.g., pamphlets, presentations, workshops), and opportunities to participate in mind, body, spirit, and general wellness activities (e.g., yoga, meditation, biofeedback, massage). Mindfulness interventions have become more popular on college campuses as of late[28] and may be an effective strategy to reduce stress in college students.[2] The majority of these studies have been condensed or modified versions of traditional Mindfulness-Based Stress Reduction (MBSR) and Mindfulness-Based Cognitive Therapy (MBCT).[2] Studies conceptualize mindfulness as a set of skills that can be learned and practiced to improve mental health and well-being.[29, 30] In addition to focusing on mindfulness components, many of these

studies also incorporate other concepts, such as cultivating self-compassion, which has been suggested to explain much of the success of mindfulness-based interventions.[31]Self-compassion has been defined as a healthy form of self-acceptance and characterized as a tendency to treat oneself kindly in the face of perceived inadequacy.[14]

Mindfulness is most commonly defined as the state of being attentive to and aware of what is taking place in the present moment[29], however researchers suggest that it is important to consider what is cultivated by meditation practices as a dispositional trait because this is sustained after the meditation practice ends.[32] The development of scales to determine these trait changes in mindfulness were developed in 2001.[7, 33, 34] Since then there have been many measures of trait mindfulness developed, however some measures are more extensively discussed in the research with the Five Factor Mindfulness Questionnaire (FFMQ) being the most integrated measurement of available measures.[32] The FFMQ consists of five sub-scales: observing, describing, acting with awareness, nonjudging of inner experience, and nonreactivity to inner experience.[35] This questionnaire may reflect the important facets that lead to the development of trait mindfulness.[32] In order to determine if an intervention is developing mindfulness these trait questionnaires should be used to represent that mindfulness was learned as a skill and not just representative of a momentary mindful state.

Mindfulness is learned and developed through informal practices (i.e., applying mindfulness to daily life) and formal practices (e.g., primarily meditation and some yoga). Meditation as a formal practice of mindfulness can be categorized as either transcendental (or sometimes referred as concentration meditation) or insight meditation (or sometimes referred to as awareness meditation).[29] Transcendental (i.e., concentration)

is thought to develop attention. The practice includes focus of attention on a fixed internal (i.e., breath, a word, phrase or mantra, etc.) or external object (i.e., candle). Insight meditation is thought to develop awareness by bringing consciousness to the moment through an attention to the present experience (i.e., sensations, thoughts, feelings). Meditation is typically practiced implicitly or explicitly with an intention to cultivate self-compassion as well as compassion toward other beings.[31]

In a recent narrative synthesis of studies on the effects of mindfulness meditation on stress and mindfulness with some reporting self-compassion in college students, 16 of the 22 studies reported significant decreases in self-reported stress. Only 45% of the studies measured mindfulness (n=10) and of those, eight studies reported significant increases in mindfulness. Only three studies in the narrative synthesis measured self-compassion with all reporting significant increases. Significant findings were demonstrated in interventions ranging from 2.25 hours to as much as 30 hours of total required participation in meditation over the course of the intervention (e.g., 3-8 wks). Many studies had a component of education similar to traditional mindfulness-based stress reduction or mindfulness-based cognitive therapy programs.[33, 36-40] Those that did not have an education component used mindfulness practices (i.e., somatic relaxation, hatha yoga, walking meditation, sitting meditation, body scan, etc.).[12, 41-49] Both mindfulness education and mindfulness practice elicited a significant decrease in self-reported stress and an increase in mindfulness.

Common limitations among the studies were low adherence rates, lack of a control group, and small sample sizes.[2] Several of the studies demonstrated high dropout rates of 30-33%.[12, 36] Deckro and colleagues reported only 43% of students attended all

six of 90-minute in-person meditation sessions across six-weeks. One home-based study reported a dropout rate of 37.5% throughout the 8-wk study with only 64% of participants completing an average of 26.7 days of a 30-minute CD meditation during the 56-day trial.[49] Due to the promise of using mindfulness meditation to reduce stress and improve mindfulness in college students combined with the limitations to adherence of in-person and home-based interventions, there is a need to explore other modalities in which to deliver mindfulness meditation to college students.

A recent study conducted a search for "mindfulness" applications in iTunes and Google Apps Marketplace and found a total of 560 applications that were accessible and in English.[50] Few studies have examined the efficacy of mindfulness-based applications. To date, there is no literature using a mobile meditation application in college students. Approximately 85% of college students own a smartphone.[51] Young adults (i.e., 18-22 year olds) are more likely to download apps than any age group with average usage ranging from one to five applications per day.[52] In a survey to determine attitudes of mobile health applications, undergraduate students reported their first app design topic of choice would be diet and physical activity (n=744, 50%) followed by stress management (n=355, 21%).[53] College students have expressed a desire for stress management applications because "college life is stressful" and students report needing an app to "'relieve some tension"' and many just "'need support"'.[53] The high prevalence of smartphone ownership, application usage, and a desire for stress management applications provides justification to explore mobile applications targeted to reduce stress and improve mindfulness in college students.

Calm is a consumer-based mindfulness meditation mobile application that offers a range of mindfulness meditations that vary in length, instruction, and content. Participants can meditate using the 'daily Calm' or may choose from a number of programs offering multi-day meditations specific to goals (i.e., happiness, self-esteem). Calm also offers other individual guided and unguided meditations. Calm may be an effective approach to significantly decrease stress and improve mindfulness in college students. The purpose of this study is to report adherence to a consumer-based mindfulness meditation mobile application (i.e., Calm) and test its effects on stress, mindfulness, and self-compassion in college students. We will also explore what the relationship is between mindfulness and the health behaviors (i.e., sleep disturbance, alcohol consumption, physical activity, fruit and vegetable consumption) often associated with elevated stress in college students.

LITERATURE REVIEW

The objectives of this literature review are to: 1) Describe the adverse outcomes of unmanaged stress in college students 2) Explore the current state of evidence-based stress reduction programs among college students 3) Explore the effectiveness of mindfulness meditation interventions to reduce stress, improve self-compassion and mindfulness in college students in a face-to-face setting 4) Explore the effectiveness of mindfulness meditation interventions to reduce stress, improve self-compassion and mindfulness in college students in a home-based setting 5) Propose why a consumer-based meditation application may reduce stress and improve self-compassion and mindfulness in college students. The conceptual model (Figure 1) for the effects of mindfulness meditation on stress, self-compassion and mindfulness is below. The

conceptual model (Figure 2) for the relationship between mindfulness and health behaviors is also below.

Figure 1. Effect of mindfulness meditation on outcomes

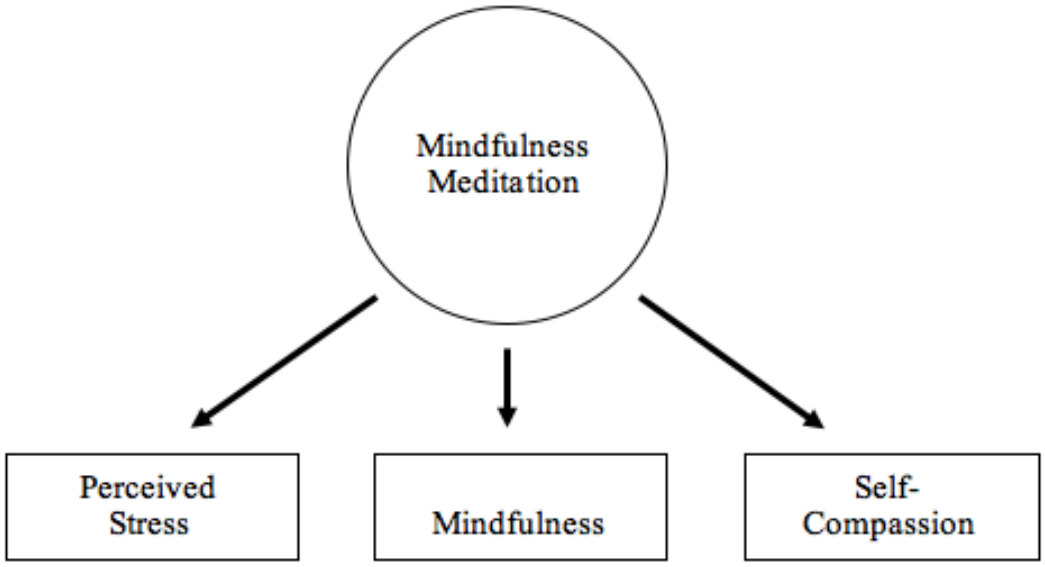
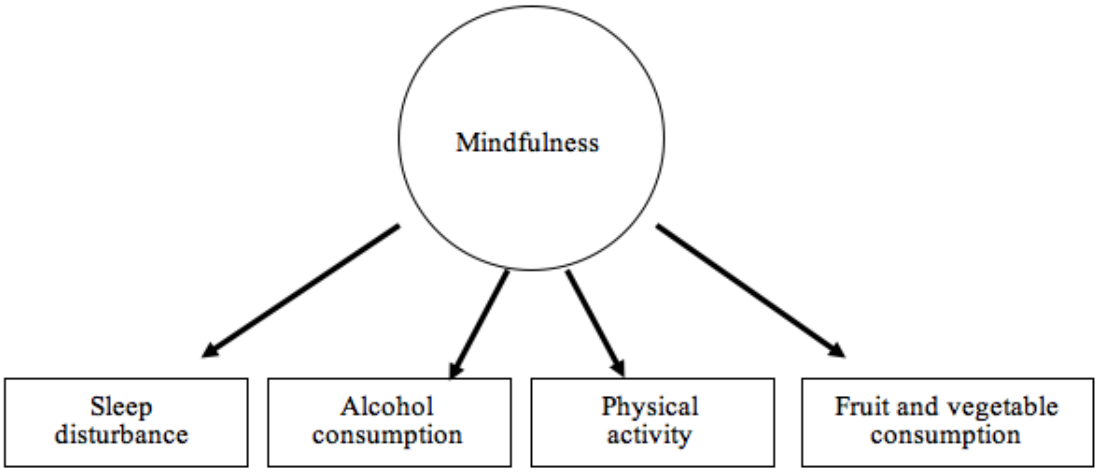


Figure 2. Relationship between mindfulness and health behaviors



Adverse Outcomes of Unmanaged Stress

College years are often considered the most stressful period in a person's life with college students reporting higher levels of stress than any other generation.[9, 12] The transition from high school to college brings about a whole new set of responsibilities, and academic, personal, and social pressures.[12] Studies suggest about 43% of students report feeling more than average stress with academic challenges and workload, change in sleeping and eating habits, new responsibilities, financial difficulties, relationships and change in social activities as the most frequently reported stressors.[17] Students report not having enough energy and/or time with 86% of college students reporting feeling overwhelmed by all they have to do.[13, 17] Evidence shows that some students are able to adjust to the imposed demands of college, but many are unable to cope and struggle with escalating stress.[13] Unmanaged elevated stress may lead to impaired academic performance, poor health behaviors, increased anxiety, depression, loneliness, and hopelessness.[13, 18, 19]

It is well established that stress is a major contributor to psychosocial and physical health.[9, 10] Leppink and colleagues surveyed 1,805 students at a Midwestern University to assess the potential associations between perceived stress and academic achievement, mental/physical health, and impulse control disorders.[9] Over half of the sample (63.6%) reported experiencing moderate to severe stress with a mean perceived stress score of 16.04 (±6.71) indicating moderate stress. This highly stressed population exhibited significantly greater depressive symptoms ($p<0.001$), worse GPAs ($p=0.001$), worse overall health ($p<0.001$), increased significant levels of impulse disorders, and higher rates of virtually all mental health problems (e.g., anxiety, mood, substance, and

eating disorders).[9] A significant inverse association was also found. Leppink also found that when stress levels increased, academic and health outcomes seemed to worsen ($p<0.001$). Stress, when coupled with anxiety and/or depression is also associated with suicide risk in college students, which is the second leading cause of death in this age group.[16, 24, 28]

Beyond the profound impact on mental health, unmanaged stress also has a potent effect on the physical health of college students with studies showing that the health choices made during this critical time may form long-term health behavior patterns.[54] This is of particular importance because studies have shown that highly stressed college students make more poor health behavior decisions than their non-stressed counterparts.[9, 20, 21] Hudd and colleagues collected data from students (N=145) at an ivy league institution where high academic stress is characteristic of the university experience. Students were asked questions regarding their health behavior in the past 24-hours. Those with high levels of stress were more likely to drink soda (72.7%) compared to the low stress group (52.4%), more likely to eat junk food (78.2%) compared to the low stress group (61.9%), less likely to exercise regularly (43%) than the low stress group (60.9%), and consumed fruits and veggies more infrequently (39.2%) compared to the low stress group (20.3%).[20] All comparisons were statistically significant.

Several other studies confirmed Hudd and colleagues' findings, also adding that more stressed students have poorer sleep quality, self-care and drug avoidance are diminished, students observe potentially detrimental eating patterns (e.g., skipping meals, restraining intake, bingeing) food preference (e.g., calorie dense), and display increased levels of impulse disorders (i.e., skin picking, compulsive sexual behavior, compulsive

buying, and gambling disorder).[9, 19, 21, 55] It is evident that unmanaged stress has detrimental effects on all aspects of health. Effective approaches to reduce stress among college students are of critical importance.

Several cross-sectional studies have demonstrated associations between mindfulness and health risk behaviors. Roberts and Danoff-Burg investigated the relationship of mindfulness to health behaviors associated with stress by administering an online survey to 553 undergraduates from a northeastern university. The reported health behaviors the researchers examined were cigarette smoking, risky sexual behavior, physical activity, sleep quality, and binge eating. Mindfulness measured by the FFMQ was significantly negatively associated with binge eating, physical inactivity, and poor sleep quality. Results suggest that individuals who are more mindful may report better sleep quality, engage in less binge eating, and may be more physically active. Gilbert and Waltz (2010) found that degree of mindfulness in everyday life predicted physical activity, fruit and vegetable intake, and self-efficacy for college students (N=269). Mindfulness was measured by the FFMQ and health behaviors and self-efficacy were measured by the International Physical Activity Questionnaire (IPAQ), National Institutes of Health (NIH) Fruit and Vegetable Screener, Exercise Confidence Survey, and Eating Habits Confidence Survey (EHCS). The results suggest that higher levels of mindfulness are related to higher levels of moderate and vigorous physical activity, exercise self-efficacy, fruit and vegetable intake, dietary self-efficacy, and lower levels of fat intake.

These studies demonstrate a relationship between mindfulness and health behaviors, however future research is warranted to explore associations. See Figure 1

above for the association between mindfulness to the health behaviors.

Evidence-based Stress Reduction Programs in College Students

Interventions to help college students cope with inevitable college stressors and their emotional reactions to those stressors have become priority among universities across the country.[26-28] Regehr and colleagues conducted a recent literature review and meta-analysis on interventions to reduce stress in university students and found only 29 controlled studies internationally.[28] The interventions were categorized into cognitive/behavioral/mindfulness-based interventions (n=24), educational interventions (n=2), art-based interventions (n=2), and other (i.e. healing touch and coaching; n=1). Regehr and colleagues' literature review demonstrated the nationwide interest in reducing stress among college students. Yet, despite stress reduction efforts on campuses, up to 50% of students have ongoing mental health issues.[22] Due to the rising prevalence of mental illnesses, and the alarming rates of suicide and suicide ideation, universities are being advised to provide opportunities to a larger number of students.[24, 25, 28] However, the most effective and feasible means of delivering a stress reduction program to college students still needs to be explored.

The most formally tested stress reduction programs to date are cognitive, behavioral, and mindfulness-based programs.[28] In a recent synthesis of the literature, Bamber and colleagues found 22 studies examining the effects of mindfulness meditation (e.g., mindfulness meditation techniques, MBSR practices, and components of mindfulness-based cognitive therapy programs) on self-reported stress and mindfulness in college students. Of those studies, 16 were found to have significant reductions in self-reported stress and 10 were found to have significant improvements in mindfulness.[2]

Several studies also looked at the effects of mindfulness meditation on self-compassion and demonstrated significant improvements.[33, 38, 40] The majority of interventions were condensed forms or modified programs based off of traditional MBSR and MBCT programs to reduce the time intensive nature of these programs for a college student population.[12, 33, 37, 42, 43, 45, 47, 56]

Face-to-face mindfulness interventions

Most of the mindfulness-based studies were conducted face-to-face on campus and taught by trained researchers or experienced meditators. In one face-to-face intervention, Myint and colleagues (2011) conducted a randomized controlled trial to evaluate the physiological effects of short-term meditation in students scheduled to take an exam. Healthy university students (n=18) were randomized to three groups: Group A- no exam (n=6), but randomized to meditate, Group B- exam (n=6), but not randomized to meditate, and Group C (n=6) exam and randomized to meditate. Those randomized to meditate were asked to meditate for one hour twice a day (morning and evening) during weekdays on campus. Measures were administered at baseline, on the eve of an academic examination and at three-weeks follow-up. Self-reported stress was measured by the Depression, Anxiety and Stress Scale (DASS). No measurements for mindfulness or self-compassion were included. Significant decreases in stress were only seen in the group with no exam and randomized to meditate ($p=0.05$). The majority of participants (83%) logged that they experienced a feeling of relaxation around 20-45 minutes, but felt uncomfortable and no longer relaxed beyond that period of time. There was no report about compliance to attending the meditation sessions. This study was limited due to a number of factors. First the small sample size limits the generalizability of its findings.

Second there was no assessment of mindfulness of participants. Without an assessment of mindfulness, it is hard to determine if the reductions in stress are actually due to being more mindful. Further research is needed to determine the effects of meditation on actual mindfulness in college students. Third, students were required to meditate for 60 minutes twice a day. In this study, students reported feelings of discomfort with longer meditation minutes and attendance was not reported. One hour twice a day may be too burdensome for college students due to busy schedules, which may be why the only group that had decreases in stress were those that meditated, but did not have a scheduled exam. There is a need to determine the dose of time in which college students are most likely to comply.

In another face-to-face meditation intervention, researchers recruited junior and senior nursing students (N=41) from a university in Korea. Participants were randomized to the experimental or control group. Prior to randomization, participants were required to listen to a 1.5-hr lecture on stress and coping. After the lecture, participants were administered their first survey, which measured stress by the psychological wellbeing index-short form (PWI-SF). Blood pressure and pulse were also taken. This was repeated at the end of the intervention. No measures of mindfulness of self-compassion were administered. The experimental group was required to attend one 90-min session a week conducted by a trained researcher for 8-wks on campus after school hours practicing mindfulness meditation, which consisted of body scans, breathing meditation, and walking meditation. The meditation was then followed by self-reflections including "recognizing one's good points, fostering a sense of gratitude, and coming to terms with one's mortality".[43] The intervention participants showed significantly reduced stress levels ($p=0.02$) at the end of the intervention, while the control group's stress levels

significantly increased over the same period. Despite the reductions in stress, this study only had 16 participants in each group, limiting the generalizability of the findings. Finally, attendance or satisfaction were not reported. It is unknown if the time requirement was met, which questions feasibility for future studies using this format.

Hindman and colleagues (2013) compared the effects of face-to-face formal and informal mindfulness meditation on measures of mindfulness, stress, and self-compassion in undergraduate and graduate students at a private mid-Atlantic university. Students were randomized to one of three groups: Mindfulness Stress Management Formal (MSM; n=13), Mindfulness Stress Management Informal (MSM-I; n=11), and a wait-list control (n=10). The interventions ran for 6-wks with an hour commitment each week. The MSM Formal program involved both an educational component and a formal (i.e., in class participation) meditation practice (i.e., sitting meditations, walking meditations, and body scans). Participants were asked to meditate for 10-15 minutes and were assigned each week either a meditation of the breath, sounds, body scan, or sounds and thoughts increasing to 30 minutes daily by the fifth week. Handouts were provided for the education component at the end of the sessions that included information about being on automatic pilot, focus on present moment, thoughts are not facts. The MSM-I program also included education, brief formal mindfulness practice (i.e., no more than 5 minutes), informal mindfulness practice (i.e., at home participation) and the same homework was given as the MSM group. The wait-list control group was only administered the same measures. They were given no handouts. The Depression, Anxiety, and Stress Scales (DASS) was used to measure perceived stress. The Five Factor Mindfulness Questionnaire (FFMQ) and the Mindful Attention Awareness Scale (MAAS) were used

to measure mindfulness. The Self-Compassion Scale (SCS) was used to measure self-compassion. Both intervention groups (i.e., MSM, MSM-I) had significant decreases in stress (MSM; $p<0.001$, MSM-I; $p<0.05$), significant increases in mindfulness measured by the FFMQ (MSM; $p<0.001$, MSM-I; $p<0.05$), and significant increases in self-compassion (MSM; $p<0.001$, MSM-I; $p<0.05$). No significant differences between groups were seen for stress or self-compassion. No significant differences were seen in either mindfulness construct until using pretest scores as a covariate, which then resulted in both intervention groups displaying significant differences compared to the wait-list control ($p=0.05$). A major limitation to this study was that 82.4% of the sample reported having prior meditation, yoga, or similar contemplative activity experience. Prior meditation experience could have confounded the results which may not be generalizable to the standard university population. Students that have already practiced the skills of mindfulness may have more easily benefited from the short meditations due to their prior experience. A brief meditation experience on the effects of stress should be further explored in those students that do not have prior meditation experience.

In another face-to-face intervention, Greeson and colleagues (2014) developed and conducted a non-traditional MBSR program entitled Koru, in which college students were trained in mind-body skills (i.e., abdominal breathing, guided imagery, insight meditation) and education (e.g., background on mindfulness practices and components) tailored specifically for college students. Koru also emphasized cultivating positive emotions such as self-compassion and gratitude. Participants were randomized to an intervention or a wait-list control group. The intervention included one 75-min class a week for 4-weeks taught in a small group format (i.e., 12-14 people). The classes were

taught through the Counseling and Psychological Services. Intervention participants (n=45) were required to attend all four classes, read the assigned chapters of "Wherever you go, there you are" by Jon Kabat-Zinn, meditate for 10-minutes on their own daily, and complete a meditation log. Measures of stress, sleep, mindfulness, self-compassion, and gratitude were given at week one and week four of the intervention. Participants had significant decreases in stress (measured by Perceived Stress Scale (PSS); $p=.037$), sleep (measured by Medical Outcome Study Sleep Scale; $p<0.005$), mindfulness (measured by Cognitive and Affective Mindfulness Scale-Revised; $p<0.005$), self-compassion (measured by Self-Compassion Scale; $p<0.005$) at post intervention. There were no improvements in gratitude measured by the Gratitude Questionnaire. Despite the significant decreases in stress only 33% of participants attended all four classes, which is similar to other studies in college students.[12, 36] The low attendance rates suggest that other modes or doses of meditation delivered to college students should be tested. A less time intensive and flexible approach needs to be explored to increase adherence to mindfulness meditation interventions.

A 2002 study conducted face-to-face by Deckro and colleagues reported significant decreases in stress (measured by PSS; $p=0.008$) through the administration of a mind/body mindfulness meditation intervention in college students. No measurements of mindfulness or self-compassion were assessed. Students (n=128) were randomized to either an experimental or wait-list control group. The experimental group received a 90-minute group-training sessions in the relaxation response and cognitive behavioral skills for 6-wks located at the University Health Services building. Instructors were staff members at the Mind/Body Medical Institute and University Health Services. Each

training session included a lecture, discussion, demonstration, relaxation-response based skills (i.e., diaphragmatic breathing, guided imagery, progressive muscle relaxation), and group discussion of weekly practice. The students were also given a manual and CD with 10-minute relaxation response exercises to practice at home. Participants were encouraged to practice outside of the sessions and were asked to complete a daily log recording their at-home practice. There was a 30% attrition with only 43% of the participants attending all six sessions throughout the study. Participants reported scheduling conflicts, too much work, and midterm exams as their main reasons for missing the sessions. Though significance was found in reducing perceived stress, participants dropped out of the study and those who remained did not participate in the prescribed amount of meditation (e.g., low adherence). This may have been due to the time and location requirement of this study, which as reported by students created scheduling conflicts and too much work. There is a need for meditation interventions that are less time intensive and flexible so that they "fit" in to a student's schedule.

In another face-to-face intervention, Lynch and colleagues (2011) conducted a feasibility study for a program called "Mindfulness-Based Coping with University Life" (MBCUL). The program was based on traditional MBSR and MBCT programs, but the material (e.g., relationship issues, binge eating) and group interaction was directed at college students. The study was a non-randomized intervention with a wait-list control group. There were ten participants in the MBCUL group and six in the control. Participants were asked to attend one, 1.5 hour face-to-face meditation session per week for eight weeks on campus. The first three weeks of the intervention followed traditional MBSR programs very closely with the educational component being on mindfulness and

its components. Each session, students participated in a traditional meditation practice (i.e., sitting meditation and body scan). From week four to seven the educational component differed from traditional MBSR including topics more student related including: stress, learning, health, communication, and relationships and how mindfulness could help. At week eight, there was a review session of skills and techniques learned throughout the intervention (i.e., past seven weeks). Measures of anxiety and depression using the Hospital Anxiety and Depression Scale, perceived stress using the PSS, mindfulness using the Frieburg Mindfulness Inventory, and personally relevant change using the Measure Yourself Medical Outcome Profile (i.e., change over time for participant chosen problems) were administered at week one and week eight of the intervention. Self-compassion was not measured. At the end of the intervention students in the intervention group had a significant reduction in stress compared to the control group (p=.03). A significant increase in mindfulness was also seen (p=0.06). Limitations of the study included: non-randomization, small sample size (n=15), low power (d=0.52), and high attrition (33%). The small sample size resulted in low power, which may overestimate the true potential effect of this intervention on reducing stress in college students. Lynch reported that a number of participants dropped out fairly quickly, but reasons for dropping out were not explored or reported. The MBCUL intervention required an intensive time commitment (i.e., 1.5 hours/wk) which could have impacted the recruitment efforts and overall attrition rate. College is considered one of the most stressful times in a person's life. Students may not have a desire to commit to additional work or additional scheduling even if it is aimed at reducing their stress.

Students report feeling overwhelmed by all they have to do (e.g., academic and social pressures, finances). Despite the effectiveness of face-to-face interventions for reducing stress in college students, many of the studies required attendance that may not be feasible for college students long-term. Students that weren't able to attend interventions reported class conflicts and time as barriers to participation. Longer meditation times were also described as uncomfortable beyond 45 minutes indicating that shorter meditation experiences need to be explored for those college students with limited meditation experience. This may also help to mitigate barriers to overall participation in mindfulness interventions in college students. The class sizes were capped at around 15 students, which impacts the number of students these interventions can reach and help. Additionally, several studies did not include measurements of mindfulness, and few examined self-compassion, both of which are considered to be of vital importance to the success of mindfulness-based interventions. There is a need to explore other strategies to deliver mindfulness meditation practices for stress reduction that limit burden (i.e., time, inconvenient location) for students. Additionally, valid measures of mindfulness and self-compassion need to be used to better understand the effectiveness of mindfulness-based interventions.

Home-based mindfulness interventions

To date there have only been two home-based mindfulness interventions in college students.[40, 49] In one study, Warnecke and colleagues (2011) implemented a single-blinded RCT with senior medical students at the University of Tasmania. Participants (N=66) were randomized to either a guided mindfulness practice (n=32) or control group (n=34). Students in the guided mindfulness practice group were asked to

listen to a CD containing 30 minutes of spoken guided mindfulness practice, daily over an eight-week period independently at home. The usual care group was not given a CD or any materials. Stress was measured by the Perceived Stress Scale (PSS) and the Depression, Anxiety and Stress Scale (DASS). Mindfulness and self-compassion were not measured in this study. Outcomes were measured at three different time points (i.e., baseline, post, and follow-up). Significant decreases in stress were reported by both the PSS and DASS scale ($p<0.05$; $p=0.05$, respectively). Over half of the participants (64%) completed an average of 26.7 days (out of 56) exhibiting modest adherence to the intervention.[49] Warnecke and colleagues indicated that students had a desire to meditate. However, the required time of 30-minutes may have contributed to the modest adherence. The feasibility of home-based mindfulness meditation interventions requiring students to meditate independently for fewer minutes at one time needs to be explored in college students.

The second home-based study compared MBCT self-help to a wait-list control group on measures of depression, anxiety, stress, satisfaction with life, mindfulness and self-compassion.[40] Seventy-nine UK University students were randomized to either an intervention (n=39) or control (n=40) group. Intervention participants were given the 8-chapter MBCT self-help book, "Mindfulness: A practical guide to finding peace in a frantic world". They were instructed to read one chapter a week and to practice a series of 20-30-minute mindfulness practices from the accompanying CD. Participants were emailed weekly reminders to read the chapters. Measures were administered prior to randomization, after the 8-wk intervention, and at 10-wk follow-up. Depression, anxiety, and stress were measured with the Depression Anxiety and Stress Scales- Short Form

(DASS-21). Mindfulness was measured using the FFMQ. Self-compassion was measured using the Self-Compassion Scale- Short Form (SCS-SF). Significant reductions in stress ($p=0.002$), mindfulness ($p< 0.001$), and self-compassion ($p<0.001$) were found at post-intervention. There were no significant changes in measures from post-intervention to follow-up in the intervention group, indicating maintenance of change. Almost 60% of the participants reported reading the entire book and a median number of reported mindfulness meditation of 2-3 times a week for 10-20 minutes. The study also reported good adherence with 80% of participants reporting they were still practicing mindfulness at the 10-wk follow-up assessment. Participants continued use of the meditation CD after the end of the intervention is a promising outcome. The mode of delivery (i.e., prerecorded CD) was an acceptable and satisfactory way to administer meditation.

Overall, both home-based meditation studies demonstrated moderate to strong engagement and adherence to meditations sessions. Students demonstrated they were motivated to practice mindfulness meditation independently. Of the 30-minutes meditation requirement, participants completed as little as 10 minutes up to the full 30-minute mindfulness sessions. Important to note is that both home-based interventions utilized CDs. This requires additional equipment (i.e., CD player, portable CD player) and CDs are not as widely used as digital devices such as iPods, media players, and smartphones. Interventions utilizing changing technology needs to be explored. Home-based meditation interventions for college students are in their infancy, but the studies reported here show promise that mindfulness interventions delivered at home may be effective for reducing stress in college students. Home-based interventions may be

feasible, effective, and an inexpensive, and way to deliver mindfulness meditation interventions to college-students.

Mobile apps and the Calm app

Approximately 85% of college students own smartphones with college students checking their phones on average every 6.5 minutes with the majority of time spent in applications.[51, 57, 58] Mobile apps have become quite popular in the last 10 years with young American adults being more likely to download apps to their phone than any other group.[52] More than 35,000 applications on the Apple Store are health related.[50] Among the health-related applications and due to the growing evidence of face-to-face mindfulness programs, the production of mindfulness applications have been on the rise. Mani and colleagues recently conducted a search for "mindfulness" applications and found a total of 560 applications that were accessible and in English.[50] Mobile apps may be an effective strategy to deliver meditation to college students to reduce stress. Young adults look for health information on their phones as almost 24% download apps for tracking or managing their health.[59] In a survey conducted by Dennis and colleagues, undergraduate students reported they are most likely to download diet and physical activity (n=744, 50%) apps followed by stress management (n=355, 21%) apps.[60] Additionally, students prefer a tracking component or a way to receive feedback about their progress. Students used mobile apps to either adopt a new behavior or support an existing one. They reported that the capability of the app to track helped them achieve their goals and raise awareness of their target behavior.[59] Students also reported the need for an app to be easy to use and cost efficient. Studies suggest college students are an ideal population to apply new health modalities.[51, 52, 59]

To date there has been one mobile application that has been formally tested for its effectiveness to improve mindfulness in college students. No interventions have assessed using a mindfulness-based mobile app to reduce stress or improve self-compassion in college students.[61, 62] Chittaro and Vianello conducted a study in college students to determine the efficacy of their developed app (i.e., AEON) to improve users practice of thought distancing (i.e., decentering) compared to two traditional thought distancing techniques (i.e., not computer based).[62] Participants (n=22) were recruited among undergraduate and graduate students at a university through direct contact. Each participant completed three thought distancing techniques (CLOUD, CARD, and AEON). The order of the techniques was counterbalanced to prevent learning effects. Participants achieved the highest level of decentering using the mobile application and the mobile app was more effective in improving thought distancing skills than the traditional techniques (i.e., cloud imagery, card-tossing). The application was also considered more pleasant and less difficult making it the preferred approach for the participants compared to the traditional techniques.[62] Significant differences were seen when comparing AEON to the traditional techniques in pleasantness ($p<0.01$), difficulty ($p<0.001$), and decentering ($p<0.05$). Although more research is warranted, the app demonstrated initial effectiveness in improving thought distancing compared to traditional approaches providing rationale to use mobile applications to practice mindfulness.

Calm is a consumer-based mindfulness meditation application based upon mindfulness meditation principles such as paying attention to our thoughts, emotions, and experiences without judgment. Calm is universal and non-denominational with partially guided and unguided meditations ranging from two minutes to an hour. Some of the

sessions introduce specific practices such as Vipassana or “insight” meditation (i.e., concentrating deeply on bodily sensations and mental events) and Loving-Kindness. The meditations closely mimic MBSR practices (i.e., body scan, walking meditations, etc.), but excludes yoga. Calm also offers music with tracks ranging from 3-5 minutes to about an hour in length and sleep stories ranging from 12-45 minutes. The app offers foundation courses such as the “7 days of Calm” or the “’Calm College Collection’”. The College Collection is different than most meditation or MBSR programs because they are specifically tailored to the needs and wants of college students. The meditations are focused on managing stress, improving focus, and achieving balance by addressing items such as anxiety, sleep, and self-esteem. Research has demonstrated the effectiveness of mindfulness meditation interventions on reducing stress and improving mindfulness and self-compassion (REF). See Figure 1 above for our proposed model for mindfulness meditation on stress, mindfulness, and self-compassion in college students.

Therefore, the purpose of this study is to report adherence to a consumer-based mindfulness meditation mobile application (i.e., Calm) and test its effects on stress, mindfulness, and self-compassion in college students. We will also explore what the relationship is between mindfulness and health behaviors often associated with elevated stress in college students.

HYPOTHESES & RESEARCH QUESTION

Hypothesis 1: Mindfulness meditation delivered via a consumer-based mobile application will significantly reduce self-reported stress as compared to a delayed start group.

Hypothesis 2: Mindfulness meditation delivered via a consumer-based mobile application will significantly increase trait mindfulness as compared to a delayed start group.

Hypothesis 3: Mindfulness meditation delivered via a consumer-based mobile application will significantly increase self-compassion as compared to a delayed start group.

Research question 1: What is the relationship between mindfulness and self-reported health risk behaviors (i.e., sleep disturbance, alcohol consumption, physical inactivity, and poor fruit and vegetable consumption) in college students who use a mobile meditation application?

METHODS

This study was approved by the Institutional Review Board at Arizona State University. All participants completed an informed consent prior to participation in the study. College students attending Arizona State University with self-reported high stress scores (i.e., a score of 14 or higher)[23, 51] on the Perceived Stress Scale (PSS) were recruited for this study to represent a typical college student. Potential participants were eligible for the study if they were: 1) a current full-time undergraduate student at Arizona State University 2) 18 years or older 3) had a score of 14 or higher on the Perceived Stress Scale (PSS) 4) owned a smart-phone 5) willing to download the CALM app 6) willing to be randomized and 7) able to read and understand English. Participants were excluded if they: 1) had a current mindfulness practice (i.e., practice 15 min or more per

day of meditation, yoga, body scan, etc. within the past 6 months)[63] 2) were currently using the Calm app or another meditation app as naïve meditators were wanted. Table 1 describes the inclusion/exclusion criteria.

Table 1. Inclusion/Exclusion Criteria	
Inclusion Criteria	Exclusion Criteria
- Current full-time undergraduate student at Arizona State University - Be 18 years or older - A score of 14 or higher on the PSS - Own a smart-phone - Willingness to download the CALM app - Willingness to be randomized - Able to read and understand English	- Currently have an established mindfulness practice - Currently use the CALM app or another meditation app

Sample Size

After accounting for 10% drop out the target sample size for this intervention was 104 students (80% power). The sample number is based on data from a previous study among college students demonstrating a significant effect on stress scores using the PSS (-3.44, 95% CI -6.20 to -0.68; $p < 0.05$).[49]

Recruitment

Participants were recruited utilizing social media (i.e., Facebook and Instagram), email listservs, flyers, and by contacting professors throughout university departments (i.e., Biology, English, Physics, etc.). Interested students were sent an eligibility survey via Qualtrics (i.e., online survey database). If eligible, participants were sent an intake video and three questions via Qualtrics. Once the video was watched and the questions were answered correctly participants were sent the informed consent and baseline questionnaire to complete via an online survey from Qualtrics. After the informed

consent and baseline questionnaire was completed participants were randomized into the intervention or delayed start group.

Research Design

The study was a randomized controlled trial. Participants randomized to the intervention group participated in an eight-week app-based meditation intervention of at least 10 minutes per day. Those randomized to the delayed start group participated in the meditation intervention after 12-weeks post follow-up assessment.

Intervention group

After randomization, the intervention group was given instructions on how to download the Calm application. Once downloaded, participants were asked to complete the "7 Days of Calm" program for the first week of the intervention to familiarize themselves with the principles of meditation. Each day of the 7 Days of Calm started with an educational component on a principle of mindfulness meditation (e.g., being present, returning to the here and now, pulling out of autopilot, etc.). After the principles were discussed a mindfulness meditation exercise was introduced (e.g., body scan, breath focus, loving kindness, etc.) After participants completed “7 Days of Calm” they were allowed to choose any meditation they desired. They could choose meditations from the College Collection, which addresses topics such as stress, sleep, self-compassion, and concentration or they could choose another series such as “7 Days of Managing Stress”. Participants were asked to complete at least 10-minutes daily of meditation. They could exceed that time limit if desired.

Delayed start group

After randomization, the delayed start group received access to the Calm app after 12-weeks following the follow-up assessment. They were administered the same surveys as the intervention group throughout the 12-wks.

Outcome Measures

Both the meditation and delayed start group were administered three surveys, baseline (week 0), post-intervention (week 8), and follow-up (week 12) to assess perceived stress using the Perceived Stress Scale (PSS), trait mindfulness using the Five Factor Mindfulness Questionnaire (FFMQ), self-compassion using the Self Compassion Scale Short-Form (SCS-SF), and health risk behaviors (i.e., sleep disturbance, alcohol consumption, physical inactivity, and poor fruit and vegetable consumption). Sleep disturbance was assessed using the Patient-Reported Outcomes Measurement Information System Short Form (PROMIS 8a), alcohol consumption, physical activity (i.e., aerobic and strength training), and dietary behaviors (i.e., fruit and vegetable consumption) was assessed by the Youth Risk Behavior Survey (YRBS). Objective meditation participation was assessed by the Calm informatics team.

Stress

Stress was measured using the Perceived Stress Scale (PSS).[64, 65] The PSS is a 10-item inventory used for the assessment of perceived stress. The scale measures the degree to which situations are appraised as stressful. An example question is, “In the last month, how often have you felt confident about your ability to handle your personal problems?”. The items are rated on a 5-point Likert scale ranging from 0 (never) to 4 (very often). The

PSS has good reliability with an alpha coefficient of .89 in an undergraduate college sample.

Mindfulness

Mindfulness was measured using the Five Factor Mindfulness Questionnaire (FFMQ).[66] The FFMQ is a 39-item self-report inventory used for the assessment of multiple constructs of mindfulness skills. The inventory assesses five subscales: observing, describing, acting with awareness, non-judging of inner experience, and non-reactivity to inner experience. An example question from the observing skillset is, "When I'm walking, I deliberately notice the sensations of my body moving". The items are rated on a 5-point Likert scale ranging from 1 (never or very rarely true) to 5 (very often or always true). The FFMQ was tested for consistency, reliability, and validity in undergraduate students with alpha coefficients for observing, describing, acting with awareness, non-judging of inner experience, and non-reactivity to inner experience as .83, .91, .87, .87 and .75, respectively. FFMQ had adequate to good test-retest reliability.

Self-Compassion Scale Short Form

Self-compassion was measured by the Self-Compassion Survey Short-Form (SCS-SF).[67] The SCS-SF is a 12-item survey assessing three subscales: self-kindness versus self-judgment, common humanity versus isolation, and mindfulness versus over-identification. An example question is, "when I fail at something important to me I become consumed by feelings of inadequacy?" The items are rated on a 5-point Likert scale ranging from 1 (almost never) to 5 (almost always). The SCS-SF is a valid and reliable measure to assess self-compassion in college students.

Patient-Reported Outcomes Measurement Information System Short Form

Sleep disturbance was measured by the Patient-Reported Outcomes Measurement Information System Short Form (PROMIS).[68] The PROMIS short-from is an 8-item inventory used to assess sleep disturbance in adults. An example questions is, “In the past 7 days, my sleep was restless…” The first seven questions follow the same pattern and are rated on a 5-point Likert scale ranging from 1 (Not at all) to 5 (Very much). The last question is rated on a reversed 5-point Likert scale ranging from 5 (Very poor) to 1 (Very good). The PROMIS short-form is considered a reliable and valid measure and has demonstrated greater measurement precision than the Pittsburgh Sleep Quality Index (PSQI) and the Epworth Sleepiness Scale (ESS).

Youth Risk Behavior Survey

Health risk behaviors (i.e., alcohol consumption, physical inactivity, and poor fruit and vegetable consumption) was measured by the Youth Risk Behavior Survey (YRBS).[69, 70] The YRBS is 99-item survey that assesses six categories of priority health-risk behaviors among youth and young adults, however for the purpose of this study only 20-items will be used. An example question is, “During the past 7 days, on how many days did you do exercises to strengthen or tone your muscles, such as push-ups, sit-ups, or weight lifting?” All questions are multiple choice. The YRBS demonstrated moderate reliability on all measures.

Independent/Dependent Variables

The independent variable in this study was mindfulness meditation. The dependent variables were self-reported stress, trait mindfulness, self-compassion, and

health behaviors (i.e., sleep disturbance, alcohol consumption, physical activity, fruit and vegetable consumption).

Statistical Analyses

Descriptive statistics (e.g., mean and frequencies) were calculated for both continuous and categorical variables by intervention and control groups. Primary outcome measures were a change in perceived-stress, mindfulness, and self-compassion between intervention and control groups after eight-weeks of the intervention. General linear models were used to examine mean differences for the primary outcome measures between groups after adjusting for covariates (age, gender, and race). The chi-square tests were used to compare frequency difference for demographic characteristics across intervention and control groups. The Pearson, Spearman, and point-biserial correlations were used to examine the association between measures in mindfulness and health risk behaviors (i.e., sleep disturbance, alcohol consumption, physical inactivity, and poor fruit and vegetable consumption) at post intervention. A p-value of ≤ 0.05 will be considered statistically significant. All statistical procedures were performed using the IBM Statistical Package for Social Sciences (SPSS) version 24.0 (Armonk, NY) and Statistical Analysis Systems Software, version 9.4 (SAS Institute, Cary, NC).

RESULTS

Participant Enrollment

A total of 329 ASU students completed the eligibility questionnaire. Of those that completed eligibility, 63% (n=208) were eligible and 37% (n=121) were ineligible. The most common reasons for ineligibility were 1) Current mindfulness practice (22.7%;

n=75), 2) Low stress score (7.0%; n=23), 3) Not a full-time ASU student (5.5%; n=18), 4) Not willing to be randomized (0.9%; n=3), and 5) Not an undergrad student (0.6%; n=2). Eligible participants (N=208) were sent an intake video link via email to review the study details. Over half of those eligible (52%; n=109) completed the intake video and signed the informed consent. Fifty-six participants were randomized to the intervention group and fifty-three in the delayed start group. After removing participants those who did not complete the post-survey (n=18) or did not set up a Calm account (n=2) or those that did not meditate at all (n=1), a total of 88 participants, aged 18 to 48 years, were included in the analysis. Figure 3. describes eligibility and enrollment.

Participant Demographics

Table 2 describes the baseline characteristics of the study participants (N=88). The mean age, adjusted for gender and race, for the intervention group was 20.41 (2.31) years and 21.85 (6.3) years for the delayed start group. The majority of participants were female (n=79, 88%), freshman (n=27, 30.7%), non-Hispanic (n=66, 77%), white (n=52, 59%), no mental diagnosis (n=65, 74%) (i.e., anxiety, depression, ADHD), not currently take medications (n=77, 87.5%), and not in counseling (n=80, 90.9%). The prevalence of baseline demographic characteristics, mental diagnosis, medication use, and counseling activities were similar between intervention and control groups (all p-value >0.17). The means scores of self-reported stress (intervention, 23.12 vs. control, 21.89, P = 0.25) and self-compassion (intervention, 29.7 vs. control, 31.91, p = 0.25) were similar between intervention and control groups at baseline. The mean score of mindfulness was slightly higher in the control group (intervention, 108.55 vs. control, 114.6, p<0.001) at baseline. In addition, the means scores of sleep disturbance (intervention, 24.97 vs. control, 21.87)

and fruit and vegetable servings per week (intervention, 18.8 vs. control, 16.8) are shown in Table 3. The prevalence of binge drinking rates and monthly alcohol consumption was similar between intervention and control groups (Table 3). In the intervention, the majority did not binge drink (80%; n=33) or consume alcohol more than two days within the last month (73%; n=30). Only eight participants met aerobic activity guidelines, and 13 met strength training guidelines. Similar, the majority of control group participants did not binge drink (72%; n=34) or consume alcohol more than two days within the last month (79%; n=37). For the control group, only 7 participants met aerobic activity guidelines with 12 participants meeting guidelines for strength training. No one in either intervention or delayed response group met the national recommendations for fruit and vegetable intake (i.e., 5 servings/day; 35 servings/wk). Table 3 describes baseline health behaviors.

Figure 3. Enrollment

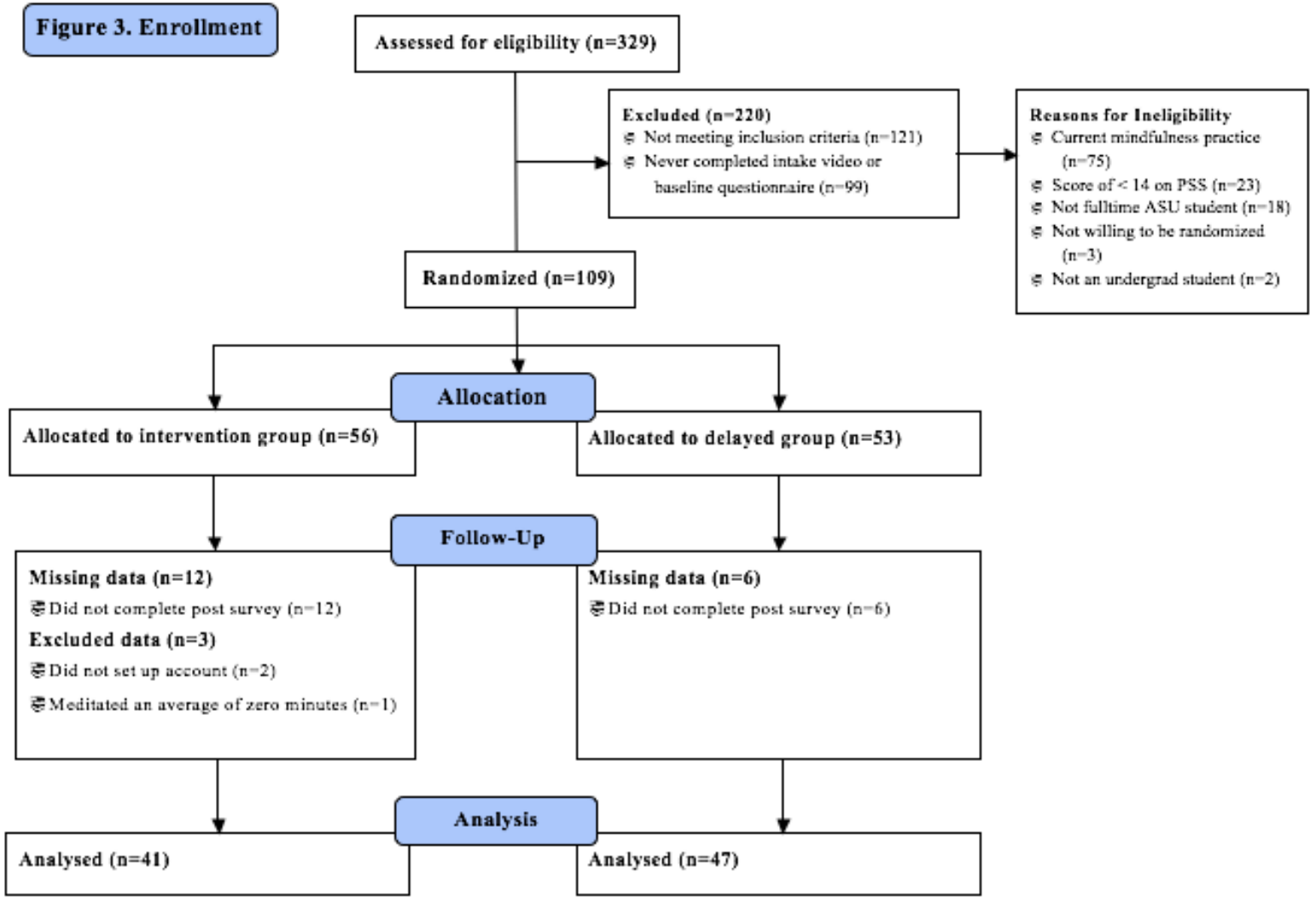


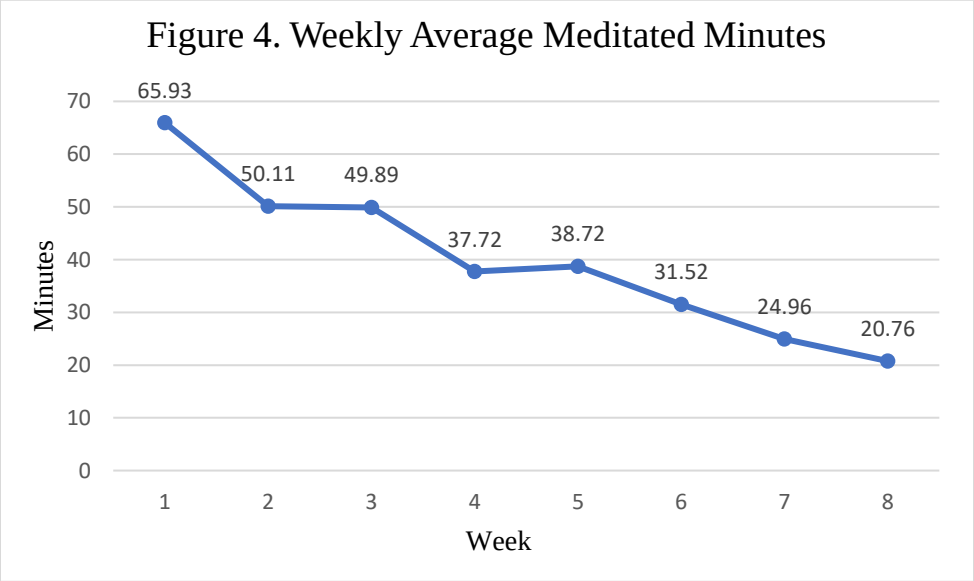
Table 2. Baseline Characteristics of Study Participants			
	Intervention (n=41)	Control (n=47)	
			p
Age, years* (M)	20.41	21.85	0.18
Gender (n, %)			0.57
Male	5 (5.7)	4 (4.5)	
Female	36 (40.9)	43 (48.9)	
Class (n, %)			0.61
Freshman	10 (11.4)	17 (19.3)	
Sophomore	12 (13.6)	10 (11.4)	
Junior	10 (11.4)	12 (13.6)	
Senior	9 (10.2)	8 (9.1)	
Ethnicity (n, %)			0.17
Hispanic	13 (14.8)	7 (8.0)	
Non-Hispanic	27 (30.7)	39 (44.3)	
Prefer not to respond	1 (1.1)	1 (1.1)	
Race (n, %)			0.54
White/Caucasian	25 (28.4)	23 (26.1)	
Asian/Asian American	6 (6.8)	9 (10.2)	
Black	1 (1.1)	4 (4.5)	
Bi-racial/Multi-racial	3 (3.4)	7 (8.0)	
Other	3 (3.4)	2 (2.3)	
Prefer not to respond	3 (3.4)	2 (2.3)	
Mental Diagnosis (n, %)			0.53
Yes	12 (13.6)	11 (12.5)	
No	29 (33.0)	36 (40.9)	
Medications (n, %)			0.94
Yes	5 (5.7)	6 (6.8)	
No	36 (40.9)	41 (46.6)	
Counseling (n, %)			0.20
Yes	2 (2.3)	6 (6.8)	
No	39 (44.3)	41 (46.6)	
Adjusted values** (M, SD)			
PSS	23.10 (5.22)	21.89 (4.58)	0.25
FFMQ	108.55 (20.04)	114.60 (16.10)	<0.001
SCS-SF	29.74 (8.69)	31.91 (7.71)	0.25

*Adjusted for gender, race: **Adjusted for age, gender, race: PSS: Perceived Stress Scale; FFMQ: Five Facet Mindfulness Questionnaire; SCS-SF: Self-Compassion Scale (short form).

Table 3. Baseline Health Behaviors									
Alcohol	**p**		**0 Days**	**1 to 2 days**	**3 to 5 days**	**6 to 9 days**	**10-19 days**	**20 +**	
Binge Days/Mon	0.624	Int	33 (37.5)	6 (6.8)	2 (2.3)	0 (0.0)	0 (0.0)	0 (0.0)	
		Con	34 (38.6)	10 (11.3)	2 (2.3)	1 (1.1)	0 (0.0)	0 (0.0)	
Days Drank/Mon	0.848	Int	16 (18.2)	14 (15.9)	6 (6.8)	4 (4.5)	1 (1.1)	0 (0.0)	
		Con	24 (27.3)	13 (14.8)	6 (6.8)	3 (3.4)	1 (1.1)	0 (0.0)	
Physical Activity			**0 min**	**0-30 min**	**31-60 min**	**61-90 min**	**91-120 min**	**121-150 min**	**150 + min**
Aerobic /Wk	0.569	Int	9 (10.2)	2 (2.3)	9 (10.2)	9 (10.2)	2 (2.3)	2 (2.3)	8 (9.1)
		Con	11 (12.5)	7 (14.9)	8 (9.1)	6 (6.8)	5 (5.7)	3 (3.4)	7 (8.0)
			0 Days	**1-2 days**	**3-6 days**	**7 days**			
Strength /Wk	0.846	Int	17 (19.3)	11 (12.5)	11 (12.5)	2 (2.3)			
		Con	23 (26.1)	12 (13.7)	12 (13.7)	0 (0.0)			
Veg/Fruit Serving			**Serving/wk**						
	0.997	Int	18.8±19.9						
		Con	16.8±13.4						
Sleep			**M (SD)**						
	0.28	Int	24.27±9.11						
		Con	22.42±9.14						

Adherence

Figure 2 describes average weekly minutes of meditation. Participants engaged in an average of 38 minutes of meditation per week over the course of the study. Over half of participants (56%; n=23/41) completed more than 30 minutes per week using the Calm app with 22% (n=9/41) of participants meditating more than 60 minutes a week.



Changes in Stress, Mindfulness, and Self-Compassion

Table 4 describes the change in the primary outcome measures between intervention and control groups. All scores were adjusted for age, gender, and race. There were statistical differences in perceived stress, mindfulness, and self-compassion between intervention and control groups (all $P<0.001$). As shown in Table 4, there was a significant decrease in perceived stress in the intervention group as compared with the control group ($\Delta = 7.13$, $P<0.001$).

A significant improvement was found for mindfulness and all constructs of the FFMQ. The intervention group had an increase in total mindfulness ($\Delta=19.23$) as well as an increase in all five constructs: observe ($\Delta=3.735$), describe ($\Delta=3.528$), acting with awareness ($\Delta=4.737$), non-judging of inner experience ($\Delta=4.938$), non-reactivity to inner experience ($\Delta=3.781$). The change in each facet was significantly different between groups ($p<0.001$).

Self-compassion also exhibited significant improvements. The intervention group displayed a score increase of 8.223 compared to a score increase of 0.294 by the delayed start group. The group difference was significant favoring the intervention group ($\Delta=8.223$, $P<0.001$).

Table 4. Change Score in Outcome Measures			
	Intervention (n=41)	Control (n=47)	
Variable			p
Adjusted Values*			
PSS	-7.137	-2.013	0.0004
FFMQ	19.23	-2.408	<0.0001
Observe	3.735	-1.272	<0.0001
Describe	3.528	-0.257	0.0006
Act aware	4.737	-0.26	0.0001
Non-judge	4.938	-0.838	<0.0001
Non-react	3.781	0.138	0.0006
SCS-SF	8.223	0.294	<0.0001
*Adjusted for age, gender, race: Perceived Stress Scale; FFMQ: Five Facet Mindfulness Questionnaire; SCS-SF: Self-Compassion Scale (short form).			

Relationship between mindfulness and health behaviors

Table 5 demonstrates health behaviors at post intervention. At baseline and post intervention, there were no significant differences within groups in any health behaviors (all p-value >.110). The Pearson and Spearman correlations among the total mindfulness score and the health behaviors are reported in Table 6. Total mindfulness was significantly negatively associated with sleep disturbance (r = -.373, p <001).

Table 5. Post-Health Behaviors

Alcohol	**p**		**0 Days**	**1 to 2 days**	**3 to 5 days**	**6 to 9 days**	**10-19 days**	**20 +**	
Binge Days/Mon	0.804	Int	32 (36.4)	8 (9.1)	1 (1.1)	0 (0.0)	0 (0.0)	0 (0.0)	
		Con	35 (39.8)	10 (11.4)	1 (1.1)	0 (0.0)	1 (1.1)	0 (0.0)	
Days Drank/Mon	0.248	Int	17 (19.3)	11 (12.5)	5 (5.7)	7 (8.0)	1 (1.1)	0 (0.0)	
		Con	21 (23.9)	13 (14.8)	10 (11.4)	2 (2.3)	0 (0.0)	1 (1.1)	
Physical Activity			**0 min**	**0-30 min**	**31-60 min**	**61-90 min**	**91-120 min**	**121-150 min**	**150 + min**
Aerobic /Wk	0.243	Int	6 (6.9)	7 (8.0)	5 (5.7)	10 (11.5)	2 (2.3)	4 (4.6)	7 (8.0)
		Con	3 (3.4)	15 (17.2)	9 (10.3)	9 (10.3)	3 (3.4)	5 (5.7)	2 (2.3)
			0 Days	**1-2 days**	**3-6 days**	**7 days**			
Strength /Wk	0.787	Int	20 (22.7)	7 (8.0)	14 (16.0)	0 (0.0)			
		Con	24 (27.3)	11 (12.5)	12 (13.7)	0 (0.0)			
Veg/Fruit Serving			**Serving/wk**						
	0.070	Int	23.27±21.59						
		Con	15.83±10.85						
Sleep			**M (SD)**						
	0.148	Int	19.1±6.77						
		Con	22.11±9.48						

Table 6. FFMQ and Health Behavior Correlations

Alcohol		FFMQ Total
	Binge Days/Mo	-0.209
	Days Drank/Mo	-0.127
Physical Activity		
	Aerobic /Wk	0.209
	Strength /Wk	0.099
Veg/Fruit Serving		
		0.085
Sleep Disturbance		
		-0.373*

*p< .001

DISCUSSION

The purpose of this study was to: (1) determine the adherence to a mindfulness meditation intervention delivered via a consumer-based mobile application (i.e., Calm) (2) test its effects of Calm on stress, mindfulness, and self-compassion. We also examined the relationship of mindfulness to health-related behaviors (i.e., sleep disturbance, alcohol consumption, physical inactivity, and poor fruit and vegetable consumption) commonly associated with unmanaged stress in college students. We

hypothesized that as a result of the intervention, stress would be reduced and mindfulness and self-compassion would improve. We also explored the relationship between mindfulness and health behaviors. Our findings supported our hypothesis that a consumer-based mindfulness mobile application may significantly reduce stress and improve mindfulness and self-compassion in a college-aged population. Additionally, we found that mindfulness was negatively associated with sleep disturbance.

Stress

Findings in our study suggest a significant reduction in perceived stress after using Calm for eight-weeks in college students. To our knowledge, there are no studies in college students that have used a consumer-based mindfulness mobile application to reduce stress. However, two studies (Warnecke et al., 2011; Taylor et al., 2014) assessed the effects of meditation on stress in college students using technology (i.e., not a traditional in-person mindfulness-based intervention such as MBSR, MBCT) to deliver the intervention.[40, 49] Similar to our study, these studies were successful in reducing stress in college students. Participants were expected to meditate "on their own" or be "self-guided" but unlike our study used books and CDs as additional components of technology to deliver the meditation intervention. Even though our results are consistent with the findings reported in these studies, our study offers a more practical, accessible, and updated technology (i.e., mobile app vs CD) for delivering meditation to college students. Technology such as CDs aren't as widely used anymore.[71] Instead, college students download data and use digital media on their iPods, mp3 players, and smartphones to listen to music, watch videos, play games, and surf the web.[72] For example, approximately 85% of college students own smartphones, which they use

primarily for texting and apps.[51, 58] It is estimated that college students check their phones on average every 6.5 minutes or 150 times per day spending most of their time in applications.[57] The rise in smartphone ownership and time spent using mobile applications warrants the need to deliver mindfulness meditation in college students via mobile apps.[57, 73]

In addition to using more dated technology (i.e., CDs), both aforementioned studies used self-report to determine compliance to the intervention, which may be subject to bias. In the study by Taylor and colleagues, participants were asked to read a self-help book based on Mindfulness-Based Cognitive Therapy (MBCT) in addition to listening to a meditation CD for eight-weeks.[40] Intervention participants were instructed to read one chapter a week from a MBCT self-help book and practice a series of 10-30-minute mindfulness practices from the CD daily. Participants reported their reading progress and meditation minutes via online surveys and just over half (57.5%) reported reading the entire book. The reported median of mindfulness meditation was 2-3 times a week and 10-20 minutes per session. Warnecke et al., 2011 asked participants to use a written diary to keep track of meditation minutes of which only 64% of the participants completed the diary (N=20/31). Of those that completed the diary, participants reported listening to the meditation CD on average 26.7 days (range 0-52 days of an eight-week intervention). Though these studies had encouraging findings, results should be interpreted with caution. Self-reported data is subject to influence including social desirability, leading to estimation bias or response bias.[74] Conversely, in our study, we objectively measured mindfulness meditation minutes weekly (i.e., Calm provided weekly reports). On average, participants engaged in 38 mindfulness meditation minutes

per week and over half (56%; n=23/41) completed at least 30 minutes per week using the Calm app indicating that participants were meditating several times a week. When comparing our objective numbers with the self-reported data of Warnecke et al., 2011 and Taylor et al., 2014 we can conclude with some certainty that students complied similarly in all studies. However, to reduce bias, future studies should collect objective data to determine compliance as we cannot accurately compare the minutes meditated.

Mindfulness

Our consumer-based mindfulness meditation mobile application intervention led to significant improvements in trait mindfulness and all mindfulness constructs (observing, describing, acting with awareness, non-judging of inner experience, and non-reactivity to inner experience) assessed with the Five Facet Mindfulness Questionnaire. To date, there has been only one study that examined the efficacy of improving a mindfulness component (i.e., decentering) using a mobile application in college students. Chittaro and Vianello 2014 examined decentering, or the ability to observe one's thoughts and feelings as temporary, and reported significant improvements ($p<0.05$). Participants were split into naïve meditators or experienced mediators. Meditators were considered naïve if they had no experience or less than eight weeks of experience of daily mindfulness practice in any form (i.e., yoga, tai chi, qigong). The intervention was four weeks and participants were asked to use a mobile application aimed at helping users practice distancing from thoughts. The app allowed users to enter their thoughts and then the app would visualize them as ink written on parchment under water.[62] Decentering was measured with the Decentering Subscale of Experience Questionnaire (DEQ). Chittaro and Vianello were the first to demonstrate potential effectiveness in improving a

mindfulness construct (i.e., decentering) using a mobile application. However, this study only measured one component of mindfulness.

The first measure for mindfulness was created in 2001 and since then several other questionnaires have been created, each reflecting different characterization of mindfulness constructs.[7, 33, 34] The development of these scales allowed researchers to test the efficacy of their programs (i.e., MBSR, MBCT, etc.) in improving mindfulness. The literature supports the conceptualization that mindfulness is a multifaceted construct and therefore when implementing mindfulness interventions, it is important to examine all the constructs to better understand the concept of mindfulness and to be able to compare to other studies.[66] More studies need to be conducted that use the same validated measure for mindfulness in order to be comparable across studies. We used the FFMQ to measure mindfulness in our study because it is a valid and reliable tool and has been tested and widely used in college (and other) populations.[40, 66] Because our study included multiple constructs of mindfulness and there is only one study that used a mobile app intervention to improve mindfulness in college students and only one construct (decentering) it is hard to compare findings. Importantly, our study demonstrated improvements in all constructs of mindfulness measured by the FFMQ despite only meditating 10 minutes daily. Other studies that have assessed the effects of meditation on mindfulness through MBSR or MBCT had more burdensome protocols (i.e., 90-min classes, certified instructors, homework, etc.) The findings of our study are extremely promising as this demonstrates that delivering meditation via a mobile mindfulness application and only having to meditate 10-minutes a day, may elicit significant improvements in mindfulness without a burdensome protocol with many components.

Self-compassion

We also observed a significant improvement in self-compassion. The literature related to improving self-compassion in college students is limited. The majority of studies looking at self-compassion have been in-person with only one using self-help and technology as an alternative to the traditional in-person format. A previously mentioned study, Hindman et al., 2013 randomized college students to one of three groups: Mindfulness Stress Management Formal (MSM; n=13), Mindfulness Stress Management Informal (MSM-I; n=11), and a wait-list control (n=10). The intervention ran for six-weeks with a class commitment of an hour each week. Participants were also told to practice at home, were given homework assignments, and asked to report weekly practice using written logs. The intervention groups differed by the mindfulness practice (i.e., formal versus informal) they received in class and were required to complete outside of class. The authors reported a significant increase in self-compassion both within intervention groups and compared to the wait-list control. Even though significant findings were reported only 37.5% of intervention participants (n=24) attended all six classes with participants only meeting half of the at-home meditation requirement throughout the intervention.

In another study conducted in college students, Greeson and colleagues implemented a four-week mindfulness intervention with weekly 75-min classes. Participants were also asked to meditate for ten minutes a day, (similar to our study), but also complete a daily meditation log, and read the required chapters from the course book. Greeson et al., 2014 reported significant increases in self-compassion, but like Hindman and colleagues also reported low attendance with only 33% of participants

attending all four classes. Participants completed only 2-3 days of at-home meditation a week averaging less than half (i.e., 30 minutes) of the required amount (i.e., 150 minutes). There is a need to consider the amount of time that college students have to spend in an intervention when implementing studies to increase adherence and compliance.[38] Studies conducted in college students using mindfulness meditation as the intervention have focused on reducing time spent by modifying the traditional MBSR and MBCT interventions by duration of the intervention and session length. For example, MBSR and MBCT requires 27 hours of class time over eight-weeks plus the prescribed 45-minutes a day of meditation practice and informal homework practices.[6, 38] Students that weren't able to attend interventions reported class conflicts and time as barriers to participation.[12]

It is well known that college students regularly fail to adhere to interventions.[12, 33, 38, 43, 49] College students report not having enough energy and/or time with 86% saying they are overwhelmed by all they have to do.[13, 17] Even with reducing duration of the intervention or session length (minutes) studies, studies in college students still report low attendance with percentages ranging from only 33-43% of the sample attending prescribed sessions.[12, 38] Importantly, in our study 56% completed at least 30 minutes per week of meditation and we found significant improvements in self-compassion. Future research needs to explore duration of the intervention and session length (minutes) prescribed to improve adherence and compliance in college students.

Mindfulness and health behaviors

We examined the relationship of mindfulness to the health-related behaviors (i.e., sleep disturbance, alcohol consumption, physical inactivity, and poor fruit and vegetable

consumption) commonly associated with unmanaged stress in college students. We found a significant negative association between total mindfulness score and sleep disturbance. Total mindfulness score was not associated with any other health behaviors. The literature suggests that higher levels of stress are associated with poor health behaviors in college students such as poor sleep, increased alcohol consumption, less exercise, and the consumption of less fruits and vegetables.[9, 20, 21] Mindfulness has been demonstrated to be an effective strategy to reduce stress and may moderate the effects of stress that leads to poor health behaviors.[2, 9] No studies have looked at the relationship between mindfulness and health behaviors after participation in a consumer, smartphone-based mindfulness mobile application in college students or after any mindfulness intervention in college students. There have been some studies that have looked at the relationship between mindfulness and health behaviors, using a cross-sectional design.[19, 75, 76] Roberts and Danoff-Burg investigated the relationship of mindfulness to health behaviors associated with stress by administering an online survey to 553 undergraduates. Participants self-reported cigarette smoking, risky sexual behavior, physical activity, sleep quality, and binge eating. Mindfulness was significantly negatively associated with binge eating, physical inactivity, and similar to our study, poor sleep quality.

Research suggests that relaxation is one of the key mechanisms of mindfulness.[19] Caldwell et al., 2010 found that greater mindfulness in college students was associated with an improvement in relaxed mood, which in turn was associated with less sleep disturbance. They also found that an increase in mindfulness was associated with a reduction in negative arousal, which in turn was associated with a reduction in sleep disturbance. Poor sleep quality has been associated with poor academic performance and

problems with mental and physical health in college students.[77] College students who sleep well are more likely to report less fatigue, depressive symptoms, and less physical symptoms (i.e., illness, increased heart rate, rapid breathing, etc.).[78] Due to the impact that sleep disturbance may have on college students' physical and mental health, future studies are warranted to determine the potential for mindfulness to reduce sleep disturbance.

We did not find a relationship between total mindfulness and the health behaviors of alcohol consumption, physical activity, and fruit and vegetable consumption. The cross-sectional studies in which we compare our findings had moderate sample sizes ranging from 269-553. Our smaller sample size (N=88) could have reduced our ability to detect relationships between mindfulness and health behaviors. Research in other populations has demonstrated that general mindfulness programs have limited effects on improving specific health behaviors.[79] Participants in stress-reduction programs may not be particularly motivated to reduce health risk behaviors in addition to dealing with their stress. Papies 2017 suggests that mindfulness interventions may be most effective if targeted at a specific behavior (i.e., reducing alcohol consumption, healthy eating, reducing smoking, etc.). There is a need for randomized controlled trials in college students to determine if mindfulness interventions tailored at improving specific health behaviors are effective.

Limitations

Although this study found significant reductions in stress among college students it was not without its limitations. The first limitation is that the majority of the sample was both white and female, which could potentially lead to a biased sample that may only

be generalized to this population. However, this is not unlike other studies in the mindfulness literature regardless of being an in-person intervention or technology-based.[12, 40, 49] Future research should aim to recruit a more diverse sample possibly by blinding participants to the type of activity and recruit as a "stress management intervention". Another potential solution could be conducting qualitative interviews with a diverse group of students to better understand how they want to be recruited (i.e., social media, through school organizations, through professors) or what messaging would entice them to participate. Secondly, we did not report follow-up data, so we do not know if the effects on mindfulness and stress were sustained or if participants continued to meditate by using the app after the intervention ended, however the majority of participants (n=29, 71%) did report they were either extremely likely or likely to continue to use the Calm app. The third limitation is that we relied exclusively on self-report scales to measure perceived stress, mindfulness, and health behaviors, which could lead to biased results due to socially desirable responding by participants. Future research should include more objective measures such as cortisol measurements or using validated devices to objectively measure physical activity and sleep. The fourth limitation was that enrollment was on a rolling basis, so participants were entering the study at different points in the semester. Information regarding their school schedule (i.e., homework load, test times, etc.) was not collected, therefore it is unknown how these factors could have played a role in their participation or stress scores. Finally, we did not collect any information to determine if students were participating in any other stress management techniques such as listening to music, art, reading, prayer, etc. which may have affected stress scores post intervention. We did collect information on physical activity, counseling, and medication

use with 77% participating in some physical activity, 9% receiving counseling, and 13% using medications. Information about music, art, reading, prayer etc. is important to understand what other stress management techniques students are using and how to design future interventions/programs for college students that may improve stress and are nonpharmacological.

Suggestions for future research

Research investigating the use of mobile applications to deliver mindfulness meditation among college students to improve mental and physical health is in its infancy. However, based on the positive findings of this study, there is a need to further explore the use of mobile apps to improve stress and other factors associated with stress (i.e., mindfulness, self-compassion, health behaviors) in college students. We present a list of future research suggestions below.

1. Compare Calm to other mindfulness meditation applications to explore application preference and comparing effectiveness in reducing stress in college students.
2. Implement interventions that are longer than eight weeks and include a follow-up assessment to see if students participate on their own once the study is over.
3. Develop mindfulness meditation sessions for an app that is tailored to an individual or a group of individuals (i.e., pregnant women, diabetics, cancer patients).
4. Develop interventions that are designed to improve a specific mechanism (i.e., self-compassion, concentration, etc.,) or develop a specific skill (i.e., mindful

eating) using a meditation application with already established programs (e.g., Calm has “7 Days of Self-Esteem).

5. Collect student transcripts and class and test schedules to determine the effects of Calm on student academics or student performance.
6. Examine the effect of Calm on stress in particular with a diverse student body.
7. Develop a mindfulness-based program targeted at a specific health behavior (i.e., reducing problematic alcohol consumption, reducing smoking, etc.)

Conclusions

An eight-week consumer-based mindfulness meditation mobile application (i.e., Calm) was effective in reducing stress, improving mindfulness, and improving self-compassion among ASU undergraduate college students. Utilizing mobile applications may be a feasible, effective, and less burdensome (i.e., components, time) way to deliver mindfulness meditation to college students. These results have powerful implications for colleges and universities across the nation. Something as simple as using a consumer-based mindfulness meditation mobile application may help students manage stress, improve mindfulness skills, and develop more self-compassion. Future research in college students is warranted.

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APPENDIX A

IRB APPROVAL LETTER

ASU Knowledge Enterprise Development

APPROVAL: EXPEDITED REVIEW

Jennifer Huberty
SNHP: Exercise Science and Health Promotion
Jennifer.Huberty@asu.edu

Dear Jennifer Huberty:

On 10/17/2017 the ASU IRB reviewed the following protocol:

Type of Review:	Initial Study
Title:	Calm College: A brief mobile app meditation intervention among stressed college students
Investigator:	Jennifer Huberty
IRB ID:	STUDY00006896
Category of review:	(7)(b) Social science methods, (7)(a) Behavioral research
Funding:	None
Grant Title:	None
Grant ID:	None
Documents Reviewed	• Followup Questionnaire_submit.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Calm College Eligibility Survey_submit.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Post Questionnaire delayed response_submit.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Post Questionnaire Intervention_submit.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Calm College Recruitment Blurbs_submit.pdf, Category: Recruitment Materials; • Calm College Informed

	Consent_Resubmit_Final_10.26.17.pdf, Category: Consent Form;

The IRB approved the protocol from 10/17/2017 to 10/16/18 inclusive. Three weeks before 10/16/2018 you are to submit a completed Continuing Review application and required attachments to request continuing approval or closure.

If continuing review approval is not granted before the expiration date of 10/16/2018 approval of this protocol expires on that date. When consent is appropriate, you must use final, watermarked versions available under the "Documents" tab in ERA-IRB.

In conducting this protocol you are required to follow the requirements listed in the INVESTIGATOR MANUAL (HRP-103).

Sincerely,
IRB Administrator
cc: Christine Glissmann
Jennifer Matthews
Linda Larkey
Tiffany Dowling
Chong Lee
Ann Sebren