Associations Between Rural-Urban Status, Health Outcomes and Behaviors, and COVID-19 Perceptions Among Meditation App Users: A Longitudinal Survey

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Abstract

Background: Rural-urban differences in health outcomes and behaviors have been well-documented, with significant rural health disparities frequently highlighted. Mobile health (mHealth) apps, such as meditation apps, are a novel method for improving health and behaviors. These apps may be a critical health promotion strategy during the COVID-19 pandemic and could potentially be used to address rural health disparities. However, limited research has assessed whether meditation app health outcomes are associated with rural/urban residence, and it is unclear whether disparities in health and behaviors between rural and urban populations would persist among meditation app users.

Objective: We aimed to explore associations between rural-urban status, psychological outcomes, and physical activity among users of a mobile meditation app. We further aimed to explore associations between rural-urban status and perceived effects of COVID-19 on stress, mental health, and physical activity, and to explore changes in these outcomes in rural vs. urban app users over time.

Methods: This study was a secondary analysis of a national survey conducted in subscribers to the meditation app, Calm. Eligible participants completed online baseline (April-June) and follow-up (June-September) surveys assessing demographics , psychological outcomes, physical activity, and perceived effects of COVID-19 on stress, mental health, and physical activity.

Results: Participants (N=8392) were female (83.9%), non-Hispanic (93.6%), White (91.8%), had high socioeconomic status (52.3% ?$100,000 income; 86.4% ?bachelor's degree) and resided in a metropolitan area core (85.7%; Rural-Urban Commuting Area 1). Rural-urban status was not associated with baseline stress, depression, anxiety, pre-COVID-19 and current physical activity, or perceived effects of COVID-19 on stress, mental health, and physical activity. Repeated-measures models showed overall decreases in depression, anxiety, and perceived effects of COVID-19 on physical activity from baseline to follow-up, and no significant changes in stress or perceived effects of COVID-19 on stress and mental health over time. Models also showed no significant main effects of rural-urban status, COVID-19 statewide prevalence at baseline, or change in COVID-19 statewide prevalence.

Conclusions: We did not find associations between rural-urban status and psychological outcomes (i.e., stress, depression, anxiety), physical activity, or perceived effects of COVID-19 on stress, mental health, and physical activity. Rural-urban status does not appear to drive differences in outcomes among meditation app users, and the use of mHealth apps should continue to be explored as a health promotion strategy in both rural and urban populations. Furthermore, our results did not show negative cumulative effects of COVID-19 on psychological outcomes and physical activity among app users, and research should further investigate mediation apps as a health promotion strategy during the pandemic.

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Conclusions: We did not find associations between rural-urban status and psychological outcomes (i.e., stress, depression, anxiety), physical activity, or perceived effects of COVID-19 on stress, mental health, and physical activity. Rural-urban status does not appear to drive differences in outcomes among meditation app users, and the use of mHealth apps should continue to be explored as a health promotion strategy in both rural and urban populations. Furthermore, our results did not show negative cumulative effects of COVID-19 on psychological outcomes and physical activity among app users in our sample (majority urban, White, female and of high socioeconomic status) Further research is needed to investigate meditation apps as a health promotion strategy in rural and urban populations.

Keywords: mHealth; rural health; physical activity; mental health; COVID-19

Introduction

Significant rural-urban differences in health outcomes and behaviors have been well-documented in the United States (U.S.).[1-6] Some studies have demonstrated poorer outcomes in urban areas, such as increased risk for certain mental disorders and cancer incidence.[1,2] However, for the majority of health outcomes and behaviors, rural residents face poorer outcomes compared to their urban counterparts, including higher chronic disease incidence and mortality rates and lower diet quality and physical activity,[3-6] underscoring the need for methods to address rural health disparities.

The use of mobile health (mHealth) apps has been rapidly growing as a novel method for health promotion,[7,8] as these strategies may be more cost-effective, scalable, and have wider reach than in-person delivered programs.[9] mHealth tools may be even more critical during the current COVID-19 pandemic given the limited availability and potential risks associated with in-person delivered programs.[10] Studies have demonstrated that mHealth apps can effectively improve mental and physical health and behaviors.[7,8] Rural areas in the U.S. are often characterized by limitations in resources such as medical facilities and specialty health care services; thus, the use of mHealth apps to remotely deliver health interventions to improve outcomes in rural populations may be of paramount importance to rural communities and help to address ongoing rural health disparities.[11,12]

The use of meditation apps, in particular, could also be used to potentially address disparities in mental health outcomes and health behaviors faced by rural residents. Meditation is a well-known strategy for improving mental health outcomes such as stress, depression, and anxiety.[13,14] Furthermore, growing literature further suggests meditation is a promising tool for counteracting sedentariness to address physical inactivity.[15] Given the poorer mental health outcomes,[16,17] lower access to mental health treatment,[17] and lower prevalence of health outcomes and behaviors among residents [18], research exploring rural-urban differences in health and behavior outcomes among meditation app users is warranted.

Limited research has assessed whether mHealth app outcomes are associated with rural/urban residence, and it is currently unclear whether disparities in health and behaviors between rural and urban populations would persist among mobile meditation app users. Thus, the purpose of this study is to: 1) explore associations between rural-urban status, psychological outcomes, and physical activity, 2) explore associations between rural-urban status and perceived effects of COVID-19 on stress, mental health, and physical activity, and 3) assess changes in psychological outcomes, physical activity, and perceived effects of COVID-19 over time among rural versus urban users of a mobile meditation app.

Methods

This study was a secondary analysis of a national survey conducted in a non-random convenience sample of paying subscribers to the mobile meditation app, Calm. All study materials and procedures were reviewed and approved by the Institutional Review Board at Arizona State University (protocol ID: STUDY00014534). Potentially eligible subscribers: 1) were ≥18 years old, 2) had opened an email from Calm and used Calm at least once in the last 90 days, 3) were able to read and understand English, and 4) were U.S. residents. Potentially eligible subscribers were identified by the Calm informatics team and were sent a study recruitment email by the research team. The recruitment email included a brief study description and the link to an online Qualtrics eligibility survey to verify that they were: 1) at least 18 years of age, 2) able to read and understand English, and 3) residing in the US or a US territory. This survey was free, voluntary, and took approximately three minutes to complete three minutes to complete.

Eligible participants were emailed a link to complete an electronic informed consent form, which stated the study purpose, who the investigator was, the length of time of the survey, which data were stored and where and for how long, potential risks and benefits, and compensation details. Eligible participants were emailed links to online Qualtrics baseline and follow-up surveys. Surveys took approximately 15 minutes to complete, were free, voluntary, and participants were able to skip survey questions.

The timeframe for this study was from baseline to approximately two months following the baseline, with baseline surveys distributed from April 22nd to June 3rd 2020, and follow-up surveys distributed from June 26th to September 11th 2020. To maintain the confidentiality, study data was imported into a secure and backed-up MySQL database. Each database user had their own username and password, with permissions set appropriately for that user. Query logging was enabled to provide an electronic audit trail that recorded all user interactions with the database. The database did not store personally identifiable information; instead, records were linked to individual participants via a unique participant ID. All participants were entered into a random drawing for one of twenty $50.00 gift cards for completing the baseline survey (i.e., 20 participants received $50.00 at baseline) and a random drawing for one of twenty $50.00 gift cards for completing the follow-up survey (i.e., 20 participants received $50.00 at follow-up) for compensation.

Measures

The online Qualtrics baseline and follow-up surveys included both investigator-developed and validated questionnaires. Participants self-reported demographic characteristics, stress (via the Perceived Stress Scale),[19] depression and anxiety (via the Hospital Anxiety and Depression Scale),[20] pre-COVID-19 and current physical activity (days/week), and the extent to which COVID-19 affected their stress, mental health, and physical activity. The Perceived Stress Scale includes 10 items that measure the degree of self-appraised stress in one's life within the past month.[21] Response items are a 5-point Likert scale from 0 = "never" to 4 = "very often." Items are summed to produce a total score from 0-40 with higher scores indicating higher levels of perceived stress. The Perceived Stress Scale is a reliable and valid measure that has demonstrated good internal consistency (Cronbach's α=.74-.91).[21] The Hospital Anxiety and Depression Scale (HADS) is a 14-item scale measuring levels of anxiety and depression. Seven items comprise the anxiety subscale

(HADS-A) and seven items comprise the depression subscale (HADS-D).[20] Response items are a 4-point Likert scale from 0 to 3. Items are summed to produce a total score from 0-21 on each subscale. Scores between 0-7 are considered normal, 8-10 is considered borderline abnormal, and 11-21 is considered abnormal. The HADS is a valid and reliable too with internal consistency reported to be up to α=0.93 and α=0.90 for the HADS-A and HADS-D subscales, respectively.[20] Participants were asked to self-report how many days/week (on scale of 0-7) of physical activity they participated in prior to COVID-19 as well as their current participation. Participants were asked, via investigator developed items, "To what extent do you feel the COVID-19 pandemic has affected your…" stress, mental health, and physical activity. Response items were a 5-point Likert scale, with higher summed scores representing a greater impact of COVID-19 on outcomes.

Participant zip codes were categorized into levels of urbanization using the U.S. Department of Agriculture's Rural Urban Commuting Area (RUCA) codes, which range from 1, indicating a metropolitan core area, to 10, indicating a rural area.[22] RUCA code definitions can be found in Table 1. To define rural-urban status, a binary variable was created by dummy-coding RUCA 1 as urban and RUCA 2-10 as rural. As an alternative approach, we also treated RUCA as a continuous variable in replicated study analyses, the results of which can be found in **Supplementary File 1.**

COVID-19 prevalence data was derived from the Centers for Disease Control and Prevention aggregate dataset of daily numbers of confirmed and probable case and deaths over time.[23] This information was used to categorize each state's relative COVID-19 risk, where low-prevalence COVID-19 states were defined as those with fewer than 10,000 cases per 100,000 at the time of survey distribution and high-prevalence COVID-19 states were those with 10,000 cases or more per 100,000. At baseline, high-prevalence COVID-19 states included California, Colorado, Connecticut, Florida, Georgia, Illinois, Indiana, Louisiana, Massachusetts, Maryland, Michigan, New Jersey, New York, Ohio, Pennsylvania, Texas, Virginia and Washington. At follow-up, high-prevalence COVID-19 states additionally included Alabama, Arkansas, Arizona, D.C., Delaware, Iowa, Kansas, Kentucky, Minnesota, Missouri, Mississippi, North Carolina, Nebraska, New Mexico, Nevada, Oklahoma, Rhode Island, South Carolina, Tennessee, Utah and Wisconsin. A binary variable, “COVID-19 state baseline”, was created based on high-prevalence COVID-19 states, and a second variable, “COVID-19 state change” was created based on states that were low-prevalence at baseline and changed to high-prevalence at follow-up.

Statistical Analysis

Descriptive statistics and frequencies were computed to describe sample characteristics. Unadjusted and adjusted regression models were used to examine the association between rural-urban status (i.e., RUCA) and 1) psychological outcomes (i.e., stress, depression, anxiety), 2) pre-COVID-19 and current physical activity, and 3) perceived effects of COVID-19 on stress, mental health and physical activity controlling for demographics (i.e., gender, age, ethnicity, race, income, education, employment, self-reported Calm app use, and statewide COVID-19 prevalence at baseline. To assess changes in outcomes over time, repeated-measures analysis of variance (ANOVA) were used. Models included baseline and follow-up outcomes (i.e., stress, depression, anxiety, effect of COVID-19 on stress, effect of COVID-19 on mental health, and effect of COVID-19 on physical activity) as within-subjects factors, rural-urban status as between-subjects factors, and gender, age, ethnicity, race, income, education, employment, self-reported Calm app use, COVID-19 state baseline (i.e., high statewide COVID-19 prevalence at baseline) and COVID-19 state change (i.e., change from low statewide COVID-19 prevalence at baseline to high statewide COVID-19 prevalence at follow-up) as covariates. To further assess the effect of rural-urban status and changes in statewide COVID-19 prevalence on changes in outcomes over time, we tested a three-way interaction with time, COVID-19 statewide prevalence, and rural-urban status. All statistical analyses were performed using SPSS 26.0 (IBM SPSS Statistics, Armonk, NY), with significance inferred at P<.05.

Results

Most participants (N=8392) were female (7041 out of 8392; 83.9%), non-Hispanic (7855 out of 8392; 93.6%), White (7704 out of 8392; 91.8%), had high socioeconomic status (4389 out of 8392; 52.3% ≥$100,000 income, 7251 out of 8392; 86.4% ≥bachelor's degree) and resided in a metropolitan area core (7192 out of 8392; 85.7% RUCA 1).

Table 1. Participant demographic characteristics (N=8392)

	n (%)
Age [mean (SD)]	47.53 (13.83)
Gender	
Female	6129 (83.92)
Male	1147 (15.71)
Other	27 (0.37)
Ethnicity	
Hispanic	436 (6.44)
non-Hispanic	6338 (93.56)
Race	
White	6586 (91.75)
Black/African American	231 (3.22)
Asian	216 (3.01)
Native American/Alaska Native	83 (1.16)
Native Hawaiian/Pacific Islander	27 (0.38)
Other	195 (2.72)
Income	
$20,000 or less	212 (3.05)
$21,000 - $40,000	402 (5.79)
$41,000 - $60,000	705 (10.15)
$61,000 - $80,000	942 (13.56)
$81,000 - $100,000	1055 (15.18)
More than $100,000	3633 (52.28)
Education	
11th grade or less	8 (0.11)
High School or GED	161 (2.20)
Some college	826 (11.29)
Bachelor's degree	424 (5.79)
Two-year college/technical degree	2670 (36.48)
Graduate degree	3230 (44.13)
Employment	
Employed	5084 (69.67)
Retired	1012 (13.87)
Unemployed	477 (6.54)
Homemaker	306 (4.19)
Unable to work	252 (3.45)
Student	166 (2.27)
Rural Urban Commuting Area (RUCA)	

1 (*Metropolitan area core: primary flow within an urbanized area (UA)*)	6038 (85.7)
2 (*Metropolitan area high commuting: primary flow 30% or more to a UA*)	409 (5.8)
3 (*Metropolitan area low commuting: primary flow 10% to 30% to a UA*)	23 (0.3)
4 (*Micropolitan area core: primary flow within an Urban Cluster of 10,000 to 49,999 (large*	295 (4.2)
5 (*Micropolitan high commuting: primary flow 30% or more to a large UC*)	42 (0.6)
6 (*Micropolitan low commuting: primary flow 10% to 30% to a large UC*)	9 (0.1)
7 (*Small town core: primary flow within an Urban Cluster of 2,500 to 9,999 (small UC*))	121 (1.7)
8 (*Small town high commuting: primary flow 30% or more to a small UC*)	11 (0.2)
9 (*Small town low commuting: primary flow 10% to 30% to a small UC*)	11 (0.2)
10 (*Rural areas: primary flow to a tract outside a UA or UC*)	85 (1.2)

As shown in Table 2, at baseline participants reported moderate stress (*m* score=18.1, 14-26 considered moderate),[24,25] borderline abnormal levels of depression (*m* score=8.9; 8-10 considered borderline abnormal),[20] normal levels of anxiety (*m* score=5.9; 0-7 considered normal),[20] and were physically active (*m*=4.9 days/week).

Table 2. Baseline psychological outcomes, physical activity, and perceived effects of COVID-19

	M (SD)
Stress (scale: 0-40)	18.12 (6.29)
Depression (scale: 0-21)	8.89 (4.12)
Anxiety (scale: 0-21)	5.87 (3.61)
Pre COVID-19 physical activity (days/week)	4.87 (2.04)
Current physical activity (days/week)	4.89 (2.29)
Perceived effect of COVID-19 on:	
Stress (scale: 1-5)	1.82 (.80)
Mental health (scale: 1-5)	2.07 (.83)
Physical activity (scale: 1-5)	2.72 (1.29)

As shown in Table 3, in both unadjusted and adjusted regression models, rural-urban status was not significantly associated with baseline stress, depression, anxiety, physical activity, or perceived effects of COVID-19 on stress, mental health, and physical activity. In our alternative analyses treating RUCA as a continuous variable, we also found no significant associations between rural-urban status and mental health outcomes, physical activity, or perceived effects of COVID-19 (results available in **Supplementary File 1**).

Table 3. Unadjusted and adjusted regression models exploring association between rural-urban status and psychological outcomes, physical activity, and perceived effects of COVID-19

	Rural/urban Difference		
	Coefficient	SE	*P*
Unadjusted models			
Stress	0.30	0.22	.088
Depression	0.15	0.14	.285
Anxiety	-0.15	0.12	.239
Pre COVID-19 physical activity	0.08	0.07	.269
Current physical activity	0.08	0.08	.314
Perceived effect of COVID-19 on:			
Stress	-0.05	0.03	.099
Mental health	-0.07	0.03	.112
Physical activity	-0.05	0.04	.294
Adjusted models[a]			
Stress	0.02	0.22	.914
Depression	0.07	0.15	.640
Anxiety	-0.24	0.13	.070
Pre COVID-19 physical activity	0.12	0.08	.103
Current physical activity	0.16	0.09	.052
Perceived effect of COVID-19 on:			
Stress	-0.05	0.03	.090
Mental health	-0.07	0.03	.223
Physical activity	-0.02	0.05	.672

[a]Controlling for gender, age, ethnicity, race, income, education, employment, Calm app use, and statewide COVID-19 prevalence at baseline

As shown in Table 4, results from repeated-measures ANOVAs showed no significant changes in stress or perceived effects of COVID-19 on stress and mental health from baseline to follow-up. In models of depression, anxiety, and effect of COVID-19 on physical activity, there were significant main effects of time, which showed that, overall, symptoms of depression and anxiety and perceived effect of COVID-19 on physical activity decreased from baseline to follow-up. Furthermore, there were significant main effects of age on most outcomes which showed that, at baseline, older participants had greater stress, depression, anxiety, engaged in more physical activity, and perceived that COVID-19 had a greater effect on their stress and mental health. There were also significant time by age interactions in models of stress and anxiety, such that older participants had smaller decreases in stress and anxiety over time than did younger participants. Results of full models with covariates can be found in **Supplementary File 1**.

There were no significant main effects of rural-urban status, statewide COVID-19 prevalence at baseline, or change in statewide COVID-19 prevalence in any models (see Table 4). In addition, there were no significant time by rural-urban status interactions, time by statewide COVID-19 prevalence at baseline interactions, or time by change in statewide COVID-19 prevalence interactions (see Table 4). Lastly, we found no significant three-way interactions (i.e., time by statewide COVID-19 prevalence at baseline by rural-urban status, time by change in statewide COVID-19 prevalence by rural-urban status).

Table 4. Results of repeated-measures ANOVA for baseline and follow-up study outcomes

Measure	*M* (*SD*)		df, df (error)	*F*	*P*
	T1	T2			
Stress	18.013 (6.174)	17.180 (6.322)			
Time			1, 2636	0.049	.825
RUCA			1, 2636	0.160	.689
Time*RUCA			1, 2636	0.000	.986
COVID-19 state baseline			1, 2636	1.078	.299
Time*COVID-19 state baseline			1, 2636	0.015	.902
Time*COVID-19 state baseline*RUCA			1, 2636	0.116	.733
COVID-19 state change			1, 2636	0.069	.792
Time*COVID-19 state change			1, 2636	0.006	.936
Time*COVID-19 state change*RUCA			1, 2636	0.168	.682
Depression	8.832 (4.097)	8.396 (4.156)			
Time			1, 2613	3.868	.049
RUCA			1, 2613	0.017	.896
Time*RUCA			1, 2613	0.339	.561
COVID-19 state baseline			1, 2613	0.386	.535
Time*COVID-19 state baseline			1, 2613	0.112	.738
Time*COVID-19 state baseline*RUCA			1, 2613	0.047	.828
COVID-19 state change			1, 2613	0.038	.846
Time*COVID-19 state change			1, 2613	0.519	.472
Time*COVID-19 state change*RUCA			1, 2613	0.183	.669
Anxiety	5.755 (3.590)	5.474 (3.663)			
Time			1, 2613	4.648	.031
RUCA			1, 2613	0.409	.522

Time*RUCA			1, 2613	0.353	.553
COVID-19 state baseline			1, 2613	0.022	.883
Time*COVID-19 state baseline			1, 2613	0.626	.429
Time*COVID-19 state baseline*RUCA			1, 2613	1.121	.290
COVID-19 state change			1, 2613	0.211	.646
Time*COVID-19 state change			1, 2613	0.010	.918
Time*COVID-19 state change*RUCA			1, 2613	0.310	.578
Physical activity	4.930 (2.305)	4.950 (2.243)			
Time			1, 2519	0.188	.665
RUCA			1, 2519	1.227	.268
Time*RUCA			1, 2519	1.248	.264
COVID-19 state baseline			1, 2519	0.046	.831
Time*COVID-19 state baseline			1, 2519	0.659	.417
Time*COVID-19 state baseline*RUCA			1, 2519	0.779	.377
COVID-19 state change			1, 2519	0.000	.999
Time*COVID-19 state change			1, 2519	2.061	.151
Time*COVID-19 state change*RUCA			1, 2519	3.550	.060
Effect of COVID-19 on stress	1.830 (0.821)	1.790 (0.783)			
Time			1, 2487	0.717	.397
RUCA			1, 2487	0.189	.664
Time*RUCA			1, 2487	3.344	.068
COVID-19 state baseline			1, 2487	0.935	.334
Time*COVID-19 state baseline			1, 2487	2.506	.114
Time*COVID-19 state baseline*RUCA			1, 2487	1.077	.299
COVID-19 state change			1, 2487	0.002	.967
Time*COVID-19 state change			1, 2487	1.203	.273
Time*COVID-19 state change*RUCA			1, 2487	0.084	.772
Effect of COVID-19 on mental health	2.110 (0.846)	2.030 (0.821)			
Time			1, 2481	0.081	.776
RUCA			1, 2481	0.138	.710
Time*RUCA			1, 2481	0.002	.961
COVID-19 state baseline			1, 2481	0.123	.726
Time*COVID-19 state baseline			1, 2481	0.255	.614
Time*COVID-19 state baseline*RUCA			1, 2481	0.510	.475
COVID-19 state change			1, 2481	0.069	.792
Time*COVID-19 state change			1, 2481	0.006	.936
Time*COVID-19 state change*RUCA			1, 2481	0.168	.682
Effect of COVID-19 on physical activity	2.740 (1.278)	2.670 (1.261)			
Time			1, 2483	3.868	.049
RUCA			1, 2483	0.017	.896
Time*RUCA			1, 2483	0.339	.561
COVID-19 state baseline			1, 2483	0.386	.535
Time*COVID-19 state baseline			1, 2483	0.112	.738
Time*COVID-19 state baseline*RUCA			1, 2483	0.047	.828
COVID-19 state change			1, 2483	0.038	.846
Time*COVID-19 state change			1, 2483	0.519	.472

Time*COVID-19 state change*RUCA	1, 2483	0.183	.669

Discussion

In this study, we explored associations between rural-urban status, psychological outcomes, and physical activity in meditation app users. We additionally explored associations between rural-urban status and perceived effects of the ongoing COVID-19 pandemic on stress, mental health, and physical activity, and changes in study outcomes in rural vs. urban app users over time. Overall, we found no significant associations between rural-urban status, psychological outcomes, physical activity or perceived effects of COVID-19 stress, mental health, and physical activity at baseline. We also found that there were significant decreases in depression, anxiety, and perceived effects of COVID-19 on physical activity over time, but there were no significant changes in stress, physical activity participation, or perceived effects of COVID-19 on stress or mental health. Additionally, there were no significant time by statewide COVID-19 prevalence by rural-urban status interactions.

Our findings generally contrast previous studies which demonstrated rural-urban differences in physical and mental health outcomes and behaviors.[1-6] Specifically, some studies found a higher prevalence of major mental disorders, including mood and anxiety disorders, in urban areas.[2,26] For example, one literature review concluded that living in urban cities is associated with a considerably higher risk for schizophrenia,[2] while another meta-analysis of urban–rural differences in psychiatric disorders, which was conducted on data taken from twenty population survey studies, found that prevalence rates for psychiatric disorders were significantly higher in urban areas compared with rural.[26] Other studies found a higher prevalence of depression in rural areas,[16] and have shown rural residents receive less mental health treatment despite poorer mental health.[17] For example, a cross-sectional study using the National Health Interview Survey found depression prevalence was significantly higher among rural than urban populations.[16] Another study using data from the Medical Expenditure Panel Survey concluded that the odds of receiving any mental health treatment and specialized mental health treatment are 47% and 72% higher, respectively, for metropolitan residents for those living in the most rural settings.[17]

Regarding health behaviors such as physical activity, rural residents have consistently been less physically active compared to their urban counterparts, which has been attributed to increased barriers and limited physical activity resources in rural areas.[6,18,27] For example, an analysis of data from the Behavioral Risk Factor Surveillance System (BRFSS), conducted among 398,208 adults, demonstrated that residents of nonmetropolitan counties had a lower prevalence of meeting national physical activity guidelines compared to their metropolitan counterparts.[18] These referenced studies exploring rural-urban differences in health outcomes and behaviors have generally been conducted in adults outside the context of participation a behavioral health intervention or use of an available behavioral health program, unlike the current study, which explored these differences among users of a meditation app.

This was the first study, to our knowledge, to assess rural-urban differences among meditation app users during the COVID-19 pandemic. Our results suggest the rural residents in our sample who use meditation apps have access to tools that may address rural health disparities. For example, meditation app users need to own a mobile device and have internet access, which are social determinants of health.[28] Furthermore, mobile meditation app users likely possess digital literacy (i.e., ability to understand and utilize electronic resources or identify, access, and use electronic information from networks as well as the skills to decipher texts, sounds, or image).[29,30] Lastly, seeking out, downloading and using a meditation app to manage health-related outcomes and symptoms reflects health literacy (i.e., capacity to obtain, process, and understand basic health information and services needed to make appropriate health decisions)[31] and is associated with mHealth app use.[32] Overall, a combination of mobile device ownership, internet access, and digital and health literacy may be important tools for addressing rural health disparities. The use of a meditation app, specifically, may further contribute to addressing disparities via improvement of mental health outcomes and health behaviors in rural residents. Thus, research should continue to explore and establish the use of meditation apps for health promotion in both rural and urban populations.

There were no associations between rural-urban status and perceived effects of the COVID-19 pandemic on stress, mental health, or physical activity. Emerging literature has demonstrated stress and symptoms of anxiety and depression are common psychological responses to COVID-19,[33] but studies have not yet focused on rural populations or assessed rural-urban differences in perceived effects of COVID-19. Our results suggest that during this ongoing pandemic, mobile device ownership, internet access, digital and health literacy, and meditation app use may address disparities related to the perceived effects of COVID-19 on health and health behaviors. This further reinforces the importance of using meditation apps among both rural and urban populations. However, it is important to note that our sample largely consisted of non-Hispanic White women with relatively high socioeconomic status, and may not be reflective of rural or urban mHealth app users from lower-income or racial/ethnic minority backgrounds, and the benefits of meditation apps and their potential for reducing disparities must be confirmed with studies in these underrepresented populations. Furthermore, given that the majority of our sample was urban, the absence of rural-urban differences in outcomes must be confirmed in a larger, more representative sample.

We found overall decreases in depression, anxiety, and perceived effect of COVID-19 on physical activity and no overall changes from baseline to follow-up in stress, physical activity, or perceived effects of COVID-19 on stress and mental health. Prior studies have generally demonstrated a reduction in physical activity since the start of the pandemic,[34-36] and our results suggest that meditation apps may be a potential strategy for counteracting decreases in physical activity during the pandemic. Studies assessing changes in psychological outcomes over the course of the COVID-19 pandemic have resulted in mixed findings; for example, one study found increases in depression and decreases in anxiety in Argentina,[37] another study found increases in anxiety in the United Kingdom,[38] and another found no changes in stress, depression or anxiety in China.[39]

However, there have been limited studies longitudinally assessing changes in mental health outcomes during the pandemic in the U.S. Our results provide preliminary evidence that despite the increase in state-level COVID-19 cases in the U.S., there may not be negative cumulative effects of the pandemic on psychological outcomes and health behaviors among our sample (majority urban, White, female and of high socioeconomic status) of meditation app users. However, further studies are necessary to understand longer term effects of COVID-19 in this group, and to establish whether meditation delivered via mobile apps is an effective strategy for promoting health outcomes and behaviors over the course of the pandemic. Our results further suggest no significant effect of rural-urban status and statewide COVID-19 prevalence (both at baseline and change from baseline to follow up) on changes in outcomes over time. However, more research is needed to elucidate time-varying changes in psychological and behavioral outcomes between rural and urban meditation app users, which could help to identify at-risk groups for interventions.

Limitations

This study was the first to explore associations between rural-urban status and psychological outcomes, physical activity, and perceived effects of COVID-19 on stress, mental health, and physical activity in meditation app users. However, there were limitations that should be noted. Our sample was primarily female, non-Hispanic, White, and had high socioeconomic status, limiting generalizability of findings to other populations, such as racial/ethnic minorities and low-income individuals. The majority of our sample was further categorized as urban, with 85.7% of participants residing in the U.S. Department of Agriculture’s definition of a metropolitan core area (i.e., RUCA 1). Although these sample demographics are frequently reflected in research assessing rural-urban differences, with studies including 80-88.7% of participants residing in RUCA 1 or the highest level of urbanization,[3,40-42] future research in this area should aim to include a larger proportion of rural residents.

Furthermore, all outcomes in the current study were assessed in this study via self-report measures, which are subject to social desirability and recall bias. Furthermore, another limitation was the use of investigator-developed survey questions as opposed to validated questionnaires. However, for some outcomes, such as the extent to which COVID-19 impacted outcomes, there were no validated instruments when the current study was conducted. With regard to behavioral outcomes (i.e., physical activity and meditation), future studies in this area should aim to use device-based measures. One of the outcomes to be particularly cautious about when interpreting results is physical activity. Physical activity is often over-reported by participants in research studies, with respondents reporting higher rates or more frequent activity than actual behavior warrants and causing self-reported measures of physical activity to suffer from low validity.[43] Thus, given our self-reported items for measuring physical activity in the current study, it is important to note that the current results are preliminary and must be validated in larger studies using device-based measures, which may be complemented with self-report measures to provide activity type and context. Another limitation was inherent to the study design, which included a national survey conducted among a non-random convenience sample. Although this study was able to contribute novel, preliminary findings, future research should assess associations between rural-urban status and health outcomes among mHealth app users in a randomized controlled trial in order to decrease bias and increase scientific rigor. Lastly, although we included total state-level COVID-19 cases over time in analyses, a combination of additional factors such as lockdowns, hospitalizations, and deaths may have had an influence on participants' psychological and physical activity outcomes and perceived effects of COVID-19 on health and behaviors. Further research is also needed to establish whether cumulative effects of the pandemic will become more apparent after a longer period of time.

Conclusions

Overall, we did not find associations between rural-urban status and psychological outcomes (i.e., stress, depression, anxiety), pre-COVID-19 and current physical activity, or perceived effects of COVID-19 on stress, mental health, and physical activity among users of a meditation app. Rural-urban status does not appear to drive differences in outcomes among meditation app users, and the use of mHealth apps should continue to be explored as a health promotion strategy in both rural and urban populations. Our results also did not show negative cumulative effects of COVID-19 on psychological outcomes and physical activity in our sample, and research should continue to explore meditation apps as a health promotion strategy during the pandemic.

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Authors' Contributions

JH and CS conceptualized the study and guided the study design. NB conducted the data analyses and drafted the manuscript. MP assisted with data analyses and interpretation of results. All authors critically reviewed and edited the manuscript and approved its submission.

Conflicts of Interest

NB, MP and CS have no conflicts of interest to disclose. JH is currently consulting as the Director of Science at Calm. JH has been conducting research with Calm as a partner for 6 years prior to the Director of Science role. JH directs the Scientific Advisory Board (SAB) at Calm. JH has no stock in Calm and receives no financial incentives from the sales of Calm.

References

1. Henley, Anderson R.N., Thomas C.C., Massetti G.M., Peaker B., L.C. R. Invasive Cancer Incidence, 2004–2013, and Deaths, 2006–2015, in Nonmetropolitan and Metropolitan Counties — United States. *MMWR Surveill Summ.* 2017
2. Gruebner O, Rapp MA, Adli M, Kluge U, Galea S, Heinz A. Cities and Mental Health. *Dtsch Arztebl Int.* 2017;114(8):121-127
3. Kozhimannil KB, Interrante JD, Henning-Smith C, Admon LK. Rural-Urban Differences In Severe Maternal Morbidity And Mortality In The US, 2007–15. *Health Affairs.* 2019;38(12):2077-2085
4. O'Connor A, Wellenius G. Rural-urban disparities in the prevalence of diabetes and coronary heart disease. *Public health.* 2012;126(10):813-820
5. Suliga E. Nutritional behaviours of pregnant women in rural and urban environments. *Annals of agricultural and environmental medicine : AAEM.* 2015;22(3):513-517
6. Whitfield G, Carlson SA, Ussery EN, Fulton JE, Galuska DA, Petersen R. Trends in Meeting Physical Activity Guidelines Among Urban and Rural Dwelling Adults — United States, 2008–2017. *MMWR Surveill Summ.* 2019;68(23):513–518
7. Chandrashekar P. Do mental health mobile apps work: evidence and recommendations for designing high-efficacy mental health mobile apps. *Mhealth.* 2018;4:6-6
8. Han M, Lee E. Effectiveness of Mobile Health Application Use to Improve Health Behavior Changes: A Systematic Review of Randomized Controlled Trials. *Healthc Inform Res.* 2018;24(3):207-226
9. Iribarren SJ, Cato K, Falzon L, Stone PW. What is the economic evidence for mHealth? A systematic review of economic evaluations of mHealth solutions. *PLoS One.* 2017;12(2):e0170581-e0170581
10. Centers for Disease Control and Prevention, . Healthcare Facilities: Managing Operations

During the COVID-19 Pandemic. 2020; https://www.cdc.gov/coronavirus/2019-ncov/hcp/guidance-hcf.html.

11. Mallow JA, Theeke LA, Barnes ER, Whetsel T, Mallow BK. Using mHealth Tools to Improve Rural Diabetes Care Guided by the Chronic Care Model. *Online J Rural Nurs Health Care.* 2014;14(1):43-65

12. Yin Z, Lesser J, Paiva KA, et al. Using Mobile Health Tools to Engage Rural Underserved Individuals in a Diabetes Education Program in South Texas: Feasibility Study. *JMIR Mhealth Uhealth.* 2020;8(3):e16683

13. Ostafin BD, Chawla N, Bowen S, Dillworth TM, Witkiewitz K, Marlatt GA. Intensive Mindfulness Training and the Reduction of Psychological Distress: A Preliminary Study. *Cognitive and Behavioral Practice.* 2006;13(3):191-197

14. Edenfield TM, Saeed SA. An update on mindfulness meditation as a self-help treatment for anxiety and depression. *Psychol Res Behav Manag.* 2012;5:131-141

15. Bigliassi M, Bertuzzi R. Exploring the Use of Meditation as a Valuable Tool to Counteract Sedentariness. *Frontiers in psychology.* 2020;11:299-299

16. Probst JC, Laditka SB, Moore CG, Harun N, Powell MP, Baxley EG. Rural-urban differences in depression prevalence: implications for family medicine. *Family medicine.* 2006;38(9):653-660

17. Hauenstein EJ, Petterson S, Rovnyak V, Merwin E, Heise B, Wagner D. Rurality and Mental Health Treatment. *Administration and Policy in Mental Health and Mental Health Services Research.* 2007;34(3):255-267

18. Matthews K, Croft J, Liu Y, et al. Health-Related Behaviors by Urban-Rural County Classification — United States, 2013. *MMWR Surveill Summ.* 2017

19. Lee E-H. Review of the Psychometric Evidence of the Perceived Stress Scale. *Asian Nursing Research.* 2012;6(4):121-127

20. Zigmond AS, Snaith RP. The hospital anxiety and depression scale. *Acta psychiatrica Scandinavica.* 1983;67(6):361-370

21. Lee EH. Review of the psychometric evidence of the perceived stress scale. *Asian Nurs Res (Korean Soc Nurs Sci).* 2012;6(4):121-127

22. United States Department of Agriculture. *Rural-Urban Commuting Area Codes.* United States Department of Agriculture, Economic Research Service;2020.

23. Centers for Disease Control and Prevention. United States COVID-19 Cases and Deaths by State over Time. 2020; https://data.cdc.gov/Case-Surveillance/United-States-COVID-19-Cases-and-Deaths-by-State-o/9mfq-cb36.

24. Menon P, Chaudhury S, Saldanha D, Sahu S, Singh V, Pathak V. Stress levels and its association with self-harm and risk-taking behavior in medical undergraduates. 2018;27(1):41-46

25. Sahu M, Gandhi S, Sharma MK, Marimuthu P. Perceived stress and resilience and their relationship with the use of mobile phone among nursing students. *Invest Educ Enferm.* 2019;37(3)

26. Peen J, Schoevers RA, Beekman AT, Dekker J. The current status of urban-rural differences in psychiatric disorders. *Acta psychiatrica Scandinavica.* 2010;121(2):84-93

27. Gilbert AS, Duncan DD, Beck AM, Eyler AA, Brownson RC. A Qualitative Study Identifying Barriers and Facilitators of Physical Activity in Rural Communities. *Journal of Environmental and Public Health.* 2019;2019:7298692

28. Daniel H, Bornstein S, Kane G. Addressing social determinants to improve patient care and promote health equity: an American College of Physicians position paper. *Annals of Internal Medicine.* 2018;168(8):577-578

29. Bawden D. Progress in documentation--Information and digital literacies: A review of concepts. *Journal of Documentation.* 2001;57(2):218

30. Noh Y. A study on the effect of digital literacy on information use behavior. *Journal of Librarianship and Information Science.* 2016;49(1):26-56

31. Berkman ND, Davis TC, McCormack L. Health Literacy: What Is It? *Journal of Health Communication.* 2010;15(sup2):9-19

32. Mackert M, Mabry-Flynn A, Champlin S, Donovan EE, Pounders K. Health Literacy and Health Information Technology Adoption: The Potential for a New Digital Divide. *J Med Internet Res.* 2016;18(10):e264

33. Rajkumar RP. COVID-19 and mental health: A review of the existing literature. *Asian J Psychiatr.* 2020;52:102066-102066

34. Duncan GE, Avery AR, Seto E, Tsang S. Perceived change in physical activity levels and mental health during COVID-19: Findings among adult twin pairs. *PLoS One.* 2020;15(8):e0237695

35. Tison GH, Avram R, Kuhar P, et al. Worldwide Effect of COVID-19 on Physical Activity: A Descriptive Study. *Annals of Internal Medicine.* 2020;173(9):767-770

36. Ingram J, Maciejewski G, Hand CJ. Changes in Diet, Sleep, and Physical Activity Are Associated With Differences in Negative Mood During COVID-19 Lockdown. 2020;11(2328)

37. Canet-Juric L, Andrés ML, del Valle M, et al. A Longitudinal Study on the Emotional Impact Cause by the COVID-19 Pandemic Quarantine on General Population. *Frontiers in Psychology.* 2020;11:565688

38. Kwong ASF, Pearson RM, Adams MJ, et al. Mental health during the COVID-19 pandemic in two longitudinal UK population cohorts. *medRxiv.* 2020:2020.2006.2016.20133116

39. Wang C, Pan R, Wan X, et al. A longitudinal study on the mental health of general population during the COVID-19 epidemic in China. *Brain Behav Immun.* 2020;87:40-48

40. Euler R, Jimenez E, Sanders S, et al. Rural–Urban Differences in Baseline Dietary Intake and Physical Activity Levels of Adolescents. *Preventing Chronic Disease.* 2019;16

41. Segel JE, Lengerich EJ. Rural-urban differences in the association between individual, facility, and clinical characteristics and travel time for cancer treatment. *BMC Public Health.* 2020;20(1):196

42. Margerison CE, Goldman-Mellor S. Association Between Rural Residence and Nonfatal Suicidal Behavior Among California Adults: A Population-Based Study. *The Journal of Rural Health.* 2019;35(2):262-269

43. Brenner PS, DeLamater JD. Social Desirability Bias in Self-reports of Physical Activity: Is an Exercise Identity the Culprit? *Social Indicators Research.* 2014;117(2):489-504

Supplementary Files

Multimedia Appendixes

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