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Original Article

Changes in physical activity and sleep following the COVID-19 pandemic on a university campus: Perception versus reality

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ABSTRACT

It has been hypothesized that key lifestyle behaviors of physical activity and sleep worsened in response to the Coronavirus disease (COVID-19) pandemic. However, there have been inconsistencies in findings of changes in these key lifestyle behaviors across populations likely due to the wide variety of assessment methods. The purpose of the study was to compare physical activity and sleep before and after the COVID-19 pandemic using accelerometers and self-reported behaviors. A longitudinal follow-up was conducted on students, faculty, and staff at a university campus in the United States. In the periods before March 2020 (covering the academic years of 2018–2019 or 2019–2020) and again in April–June 2021, participants completed surveys to evaluate their physical activity and sleep behaviors and wore an accelerometer. A total of 44 participants completed the survey at both timepoints and 32 completed accelerometer assessment at both timepoints. Fifty-seven percent of participants reported a perceived decline in physical activity, while 30% reported a worsening in sleep. From self-reported data, overall physical activity did not change, but there was a decrease in active transport ($p < 0.001$) and increase in domestic physical activity ($p = 0.012$). Sleep quality decreased as evidenced by an increase in Pittsburgh Sleep Quality Index scores ($p = 0.045$). There were no changes in accelerometer measured physical activity or sleep. There were no changes in physical or mental health. While perceptions of physical activity declined from prior to the COVID-19 pandemic, there were no changes in device-measured physical activity, and changes in self-reported physical activity differed by domain.

1. Introduction

Lifestyle changes in response to Coronavirus disease (COVID-19) pandemic, an infectious disease caused by the severe acute respiratory syndrome coronavirus (SARS-CoV-2 virus), included stay-at-home orders, transitions to remote work and school, loss of resources, unemployment, and increased childcare responsibilities. These pandemic-related lifestyle changes have likely influenced key health behaviors, including physical activity and sleep. Potential negative changes to physical activity and sleep negatively affect health outcomes, especially during the pandemic, including obesity[1] and mental health.[2] Thus, understanding how health behaviors change in response to stressful events may better help identify interventions to protect physical and mental health in post-pandemic times.

A systematic review of changes in physical activity post-COVID-19 found overall physical activity levels declined.[3] However, only four of these studies included device-based measures in healthy adults, and most studies used unvalidated questionnaires to collect information. Few population studies have used wrist-worn devices to measure physical activity,[4–7] but several found declines in physical activity during school lockdowns among children.[5–7] In addition to physical activity, sleep is an essential behavior for physical and mental health. Similar to physical activity research, sleep studies conducted during COVID-19 also lack device-based measures, and there are suggestions that self-reported sleep measures may be more biased during stay-at-home times due to changes in scheduling.[8]

Schools, including universities, had dramatic changes in operations due to the COVID-19 pandemic. Thus, the campus setting is ideal to study the change in health behaviors in response to the pandemic. Several studies have attempted to examine pre- and post-pandemic changes in physical activity in university populations by assessing students or

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Abbreviations

BMI	Body Mass Index
COVID-19	Coronavirus disease
DASS-21	Depression Anxiety Stress Scales 21
IPAQ	International Physical Activity Questionnaire
MICE	Multiple Imputation by Chained Equations
MVPA	Moderate-to-vigorous physical activity
PSQI	Pittsburgh Sleep Quality Index

university staff.[9–11] However, most of these studies have been cross-sectional or relied on retrospective perceptions of pre-COVID-19 activity. An early review identified 10 studies that found physical activity generally declined related to COVID-19 among university students, of which only two studies were conducted in the US, and only 1 study (outside of the US) utilized accelerometer measures.[12] Additional studies of university populations utilizing self-reported physical activity from Texas[10] and West Virginia[13] reported declines in physical activity from pre-pandemic to late spring or summer 2020; however, both used retrospective reporting to assess pre-pandemic levels. While self-reporting physical activity is prone to bias,[14] retrospective reporting may have additional recall bias, and evidence suggests that self-report and device-based measures differed during the pandemic.[15] Two studies used devices to measure physical activity pre- and post-COVID-19 in similar populations. One study conducted on young adults in Spain found a decline in self-reported and accelerometer measures of physical activity and an increase in total sleep from pre-COVID-19 lockdown in February 2020 to post-COVID-19 in late March to early April 2020.[16] A more recent study conducted among university staff in Kentucky using device measures of physical activity pre- and post-pandemic found daily steps decreased, but moderate-to-vigorous physical activity (MVPA) levels stayed the same from January 2019 to May 2020.[17]

Similar to research on physical activity in university populations, studies on changes in sleep have also lacked device-based measures of changes. A large meta-analysis of 18 sleep quality studies in university-aged students during COVID-19, found that 42% of students reported sleep disturbances.[18] International cross-sectional studies post-COVID-19 among university students found poor sleep associated with poor mental health.[19,20] During the early lockdown, longitudinal studies in university or young adult populations using actigraphy devices found that sleep duration increased.[21] Another study among young adults in the United States (US) using self-reported sleep found no changes in sleep.[22] A longitudinal study of Spanish university students found sleep quality worsened in early lockdown.[23] These differences may be due to differences in self-report measures, unique populations, or variations in lockdown protocols. To our knowledge, there are currently no studies using device-measured sleep pre- and post-COVID-19 amongst university students or staff.

Thus, research using device-based measures of physical activity and sleep and how these behaviors changed among university students and staff as a result of COVID-19 changes is needed. In addition to understanding how changes from COVID-19 affect these health behaviors, the COVID-19 pandemic offers a natural experiment to explore how these changes in behavior influence health outcomes, including mental health. The purpose of the current study was to quantify the changes in physical activity and sleep from before the start of the COVID-19 pandemic (pre-March 2020) to after (April–June 2021) in university students and staff.

2. Materials and methods

2.1. Study design and procedures

A previously established cohort used accelerometers to track physical activity and fitness and their associations with health and student success as part of the Exercise is Medicine - On Campus initiative from the American College of Sports Medicine. Participants completed in-person assessments of the five health-related components of fitness, wore an accelerometer for 7 days to assess physical activity and sleep, and completed an online questionnaire of demographics, health status, and health behavior.[24,25] Students, faculty, and staff who completed the Exercise is Medicine assessment in the 2019–2020 or 2018–2019 academic years prior to March 2020 were recruited to repeat participation in the current study during the post-COVID-19 period of April to June 2021 with undergraduate student assessments completed prior to the end of the academic semester.

For this study, pre-COVID-19 measures are those derived from assessments completed from November 2018 through early March 2020, and post-COVID-19 measures are from assessments completed between April and June 2021. The University of Arkansas campus officially transitioned to virtual instruction and work on March 19, 2020, and reopened in August 2020 with a combination of virtual and in-person classes continuing through June 2021. Both assessments kept physical activity and sleep measures consistent; however, in-person contact was minimized in the post-COVID-19 assessment period. Participants completed an online questionnaire and then were distributed accelerometers to wear for 10 consecutive days. For participants who had more than two assessments completed, only the post-assessment and most recent pre-COVID-19 assessment were included.

2.2. Participants

Participants were recruited from those individuals who completed prior Exercise is Medicine fitness assessments and were still on campus. Current students, faculty, or staff at the University of Arkansas in Fayetteville, age 18 years or above, and able to complete the questionnaire in English were included. Participants who participated in the previous fitness assessment, unless having previously indicated that they did not want to be contacted or who had graduated or left campus, were invited through email using their provided contact information during March 2021 ($n = 146$ out of 178 original participants). Of these, 53 (36% of those invited) began the online survey, and 39 (27%) expressed initial interest in completing a follow-up fitness assessment.

2.3. Ethical approval

The study was approved by the University of Arkansas Institutional Review Board (IRB Protocol# 1808138910), and all participants provided written, informed consent.

2.4. Measures

2.4.1. Accelerometers

As self-reported physical activity is biased to sociability and recall bias, 7-day 24-h (h) activity and sleep were measured using Actigraph, GT9x accelerometers (Actigraph, Florida, US). During post-assessments, participants wore the devices for 10 days. However, to be consistent with pre-measures, the current analysis only used the first 7 days. Data were processed using ActiLife (v 6.13.4) software. To estimate waking wear time from in-bed and out-of-bed times, two coders independently identified rest intervals using participant sleep and wake times reported daily in an app and visual inspection of the data. The coders re-examined the data for times that differed by more than 15 minutes (min), and the coders reached a consensus. Non-wear time was calculated using the Troiano algorithm with a 60-second (s) minimum wear period,[26] and non-wear times were visually confirmed. Waking wear days were included with 8 or more waking hours. Participants were included in physical activity analyses if they had 3 or more valid days and in sleep analyses if they had two or more sleep periods. The primary physical activity variable was vector magnitude average counts per minute. The

primary sleep variables were total sleep time and sleep efficiency.[27]

2.4.2. Self-reported physical activity and sleep

Self-report measures of physical activity and sleep were also used to add context. Physical activity context was assessed using the International Physical Activity Questionnaire (IPAQ) long form,[28] with estimates of total metabolic equivalent (MET)-min per week as the primary outcome using standardized scoring procedures.[28] To assess sleep quality, The Pittsburgh Sleep Quality Instrument (PSQI; Buysse, Reynolds III, Monk, Berman, & Kupfer, 1989) was used and scored using standardized procedures with higher scores indicating poorer sleep quality. The PSQI is a widely used and validated measure of overall sleep disturbance; Buysse, Reynolds III, Monk, Berman, & Kupfer, 1989). It is often operationalized as a global score, comprised of scores from seven different components that capture a broad spectrum of sleep quality. The global score is a reliable and clinically informative metric for overall sleep quality.[29] Individuals with a score of 5 or higher were classified as "poor sleepers".[30] Additionally, a single item was used to assess how perceived physical activity and sleep changed in response to COVID-19. The item for each behavior was, "In your opinion, have your physical activity levels/sleep changed since before COVID-19?" with a 5-item Likert scale response.

2.4.3. Survey

All participants completed an online survey that included basic demographics, health behaviors, and health status. The online questionnaire included previously validated questionnaires on physical activity, sleep, other health behaviors, and mental health constructs of overall perceived health and happiness and was administered via Qualtrics (Provo, Utah).[31] Depression, anxiety, and stress were assessed using the Depression Anxiety Stress Scales 21 (DASS-21)[32]; however, DASS-21 was not administered during year 1 of the cohort (2018–2019) due to changes in the original questionnaire. The questionnaire also included questions on COVID-19 diagnoses, symptoms, and social distancing changes (i.e., social isolation and remote working/school environments).

2.4.4. Body composition & fitness

During their initial visit, participants completed a fitness assessment. This paper's main fitness assessment measures included height and weight, which was assessed using The American College of Sports Medicine's normalized procedures.[33] Participants in years 2 and 3 also self-reported their height and weight. When both measured body mass index (BMI) and self-reported BMI were available, the correlation coefficient was 0.995 ($p < 0.001$, $n = 15$). Measured BMI was used for pre-COVID-19 and self-reported BMI was used for post-COVID-19 measures.

2.5. Statistical analyses

The pre- and post-COVID-19 data from the study participants was analyzed using a two-sample signed-rank test using the Pratt method to handle zero differences,[34] (nonparametric alternative to a paired sample *t*-test). The matched-pairs rank biserial correlation coefficient (r_{rb}), a recommended effect size statistic in such settings,[35] demonstrated the magnitude of the pre- and post-COVID-19 data effect.

During the data preprocessing stage, Multivariate Imputation by Chained Equations (MICE), also called full conditional specification, was utilized to impute missing values.[36] There was an overall 10% missingness in the data, with the highest rates of missingness for DASS-21 and sleep metrics. All other variables have less than 5% missingness, and after further exploration, data is assumed missing at random and multiple imputation is valid. MICE was conducted with a non-parametric, random forest algorithm.[37] This approach to missing value imputation results in less biased parameter estimates.[38]

All analyses were conducted in R Version 4.2.1[39] with statistical significance defined as $p < 0.05$.

3. Results

A total of 44 participants completed the survey at both timepoints and 32 completed accelerometer assessment at both timepoints. See Table 1 for a description of the sample.

3.1. Changes in physical activity

Forty-point nine percent of participants reported their physical activity decreased a lot, while 13.6% reported it increased a lot as seen in Table 2. A signed-rank test using the Pratt method to handle zero differences revealed that there was a statistically significant decrease in Active Transport physical activity from the pre-COVID-19 period (Mean = 608.8, standard deviation [*SD*] = 798.8) to the post-COVID-19 period (Mean = 254.6, *SD* = 381.4). The matched-pairs rank biserial correlation coefficient (r_{rb}) indicated this effect was large in magnitude ($p < 0.001$, $r_{rb} = 0.55$).

There was a statistically significant increase in domestic physical activity from the pre-COVID-19 time period (Mean = 646.9 MET-min/week, *SD* = 1 034.22) to the post period (Mean = 1 129.3 MET-min/

Table 1
Demographic features representative of sample participants, mean (SD) or percent.

Demographic	$n = 44$
Sex	
Male	25.0
Female	75.0
Race	
African or African American	4.5
Asian, Pacific Islander or Asian/American	11.4
White	77.3
Other	6.8
Ethnicity	
Hispanic	6.8
Non-Hispanic	93.2
Age (years)	38.0 (13.2)
Education	
High School or GED	25.0
College	29.5
Graduate School	43.2
Other	2.3
Role	
Undergraduate Student	22.7
Graduate Student	20.5
Staff	43.2
Faculty	9.1
Administration	4.5
Marital Status	
Single	52.3
Married	34.1
Separated or Divorced	11.4
Widowed	2.3
Children (% have children)	29.5
Health Conditions (% reporting having diagnosis)	
Asthma	15.9
Hypertension	6.8
Bladder	2.3
Cholesterol	11.4
Anemia	13.6
Diabetes	2.3
Previous COVID-19 Infection	18.2
Systolic Blood Pressure (mmHg)	116.5 (12.7)
Diastolic Blood Pressure (mmHg)	71.1 (9.5)
Sit and Reach (cm)	30.4 (9.7)
Maximum Number of Pushups	20.7 (15.8)
Maximal Oxygen Capacity (mL/kg/min)	34.4 (11.2)
Resting Heart Rate (bpm)	77.2 (13.7)
Total Handgrip Strength (kg)	64.73 (17.1)
Body Fat Total (%)	34.8 (12.4)

[1]Values for Categorical Variables are % and Values for Continuous Variables are Mean (Standard Deviation); GED: General Education Diploma, bpm: beats per minute.

Table 2
Changes in self-reported and accelerometer measured physical activity and sleep, mean (*SD*) or %.

	All available ($n = 44$)		Complete data ($n = 32$)	
	Pre-COVID-19	Post-COVID-19	Pre-COVID-19	Post-COVID-19
Physical Activity				
IPAQ (MET-min/week)				
Work	725.8 (1503.3)	1 177 (2644.0)	887.8 (1701.3)	945.8 (2366.8)
Active Transport	608.8 (798.8)	254.6 (381.4)	682.4 (911.4)	270.4 (384.0)
Domestic	646.9 (1034.2)	1 219.3 (1794.9)	693.1 (1111.0)	981.3 (1845.0)
Leisure	1 017.5 (1504.5)	1 039.7 (1356.1)	1 061.2 (1395.5)	839.0 (1025.5)
Accelerometer				
Days	NA	NA	7.3 (0.6)	6.9 (0.4)
Weartime	NA	NA	920.4 (62.8)	915.7 (83.5)
Vector magnitude (counts/min)	NA	NA	2 279.8 (495.4)	2 213.0 (533.9)
SD Vector Magnitude (counts/min)	NA	NA	519.4 (351.2)	471.1 (301.3)
Self-reported change in physical activity				
Decreased a lot	NA	18 (40.9 %)	NA	14 (43.85)
Decreased a little	NA	7 (15.9 %)	NA	5 (15.6 %)
Stayed the same	NA	5 (11.4 %)	NA	4 (12.5 %)
Increased a little	NA	8 (18.2 %)	NA	5 (15.6 %)
Increased a lot	NA	6 (13.6 %)	NA	4 (12.5 %)
Sleep				
PSQI score	4.9 (2.7)	5.6 (2.9)	5.2 (2.6) $n = 29$	5.9 (3.2) $n = 31$
PSQI category (% poor sleepers)	26 (59.1%)	29 (65.9%)	17 (58.6%)	20 (64.5%)
Accelerometer				
Sleep days	NA	NA	7.2 (0.8)	6.9 (0.5)
Total sleep time (min/period)	NA	NA	389.2 (64.3)	404.1 (69.2)
SD Total Sleep time (min/period)	NA	NA	58.6 (28.2)	52.6 (24.4)
Efficiency (%)	NA	NA	83.9 (6.0)	82.8 (7.1)
Self-reported change in Sleep				
A lot worse	NA	1 (2.3%)	NA	1 (3.1%)
A little worse	NA	12 (27.3%)	NA	9 (28.1%)
Stayed the same	NA	22 (50.0%)	NA	15 (46.95%)
A little better	NA	8 (18.2%)	NA	7 (21.9%)
A lot better	NA	1 (2.3%)	NA	0 (0.0%)

COVID-19: Coronavirus disease, IPAQ: International Physical Activity Questionnaire, MET-min: Metabolic equivalent minutes: PSQI: Pittsburgh Sleep Quality Index, NA: Not applicable.

week, $SD = 1\ 794.9$). The matched-pairs rank biserial correlation coefficient indicated this was a medium effect size in magnitude ($p = 0.012$, $r_{rb} = 0.39$).

There were no statistically significant changes in IPAQ self-reported leisure ($p = 0.691$, $r_{rb} = 0.07$) or work ($p = 0.305$, $r_{rb} = 0.19$) physical activity. There were also no statistically significant changes in walking ($p = 0.674$, $r_{rb} = 0.08$), moderate ($p = 0.357$, $r_{rb} = 0.17$), or vigorous ($p = 0.615$, $r_{rb} = 0.13$) intensity levels of physical activity. Additionally, there were no significant changes in accelerometer-measured physical activity ($p = 0.632$, $r_{rb} = 0.08$).

3.2. Changes in sleep

Only 2.3% of participants reported sleep declined or improved a lot, with 50% reporting no change in sleep. A two-sample paired *t*-test revealed a statistically significant increase in PSQI total scores from the pre-COVID-19 period (Mean = 5.0 score, $SD = 2.7$) to the post-COVID-19 period (Mean = 5.6 score, $SD = 2.9$). However, Cohen's *d* indicated that this effect was small in magnitude ($p = 0.045$, $d = 0.26$). While PSQI total scores significantly increased during the time period, the percentage of participants categorized as "poor" sleepers did not significantly increase ($p = 0.330$, $\varphi = 0.07$). There were no statistically significant changes in accelerometer-measured sleep ($p = 0.243$, $r_{rb} = 0.34$).

3.3. Changes in health

A signed-rank test using the Pratt method to handle zero differences revealed a non-statistically significant change in BMI from the pre-COVID-19 time period (Mean = 25.9 $kg{\cdot}m^{-2}$, $SD = 5.6$) to the post-COVID-19 time period (Mean = 26.1, $SD = 5.7$). The matched-pairs rank biserial correlation coefficient indicated that the observed effect was small in magnitude ($p = 0.477$, $r_{rb} = 0.12$).

Overall self-reported health, while not significantly associated with the time period ($p = 0.797$, Cramer's $V = 0.14$), did worsen during the study period for 25% of participants.

Overall self-reported happiness, while not significantly associated with the time period ($p = 0.375$, Cramer's $V = 0.22$), did worsen during the study period for over 34% of participants.

There were no statistically significant changes in depression ($p = 0.276$, $r_{rb} = 0.24$), anxiety ($p = 0.503$, $r_{rb} = 0.15$), or stress ($p = 0.255$, $r_{rb} = 0.20$) as reported on the DASS-21.

4. Discussion

Overall, this study examined the changes in physical activity and sleep from prior to the COVID-19 pandemic to post-pandemic in April–June 2021 using device-based, self-reported, and perceived measures of movement behaviors. While most participants perceived a decrease in physical activity, there were no overall changes in total self-reported or device-measured physical activity. However, active transport physical activity decreased while domestic activity increased. Half of the participants reported no perceived changes in sleep, with 30% reporting worsening sleep and 20% reporting improvements in sleep. There was a decrease in self-reported sleep quality but no changes in device-measured sleep. There were no changes in physical or mental health.

The current study provides additional information about behaviors following the COVID-19 pandemic. Compared to previous studies that examined changes in physical activity in mid-2020 during strict lockdowns, this study assessed physical activity and sleep prior to March 2020, and again from April to June 2021, after most strict lockdowns had ended. Evidence has suggested that the pandemic may permanently affect behaviors, as activity levels have not returned to pre-pandemic levels despite improvements since initial lockdowns.[40] Our findings may indicate more of a change in the longer-term changes post-pandemic in essential ways that school and work changed, as indicated by the domain-specific findings. For example, hybrid and flexible work and school environments may decrease the amount of active travel while increasing domestic activity due to increased time spent in the home. This change could have important implications for physical activity interventions in order to account for work- or school-from-home environments that are different from traditional workplace and school physical activity interventions.[41,42]

Despite the delayed post-pandemic assessment period, the current study did still find similar results to previous research that found declines in physical activity and worsened sleep. A study in Texas asked students about their perceptions of changes in physical activity and diet from pre-pandemic until November 2020 and then retrospective reports of physical activity at both time points, not using a standardized physical activity questionnaire. The authors reported that 89% of participants reported changes in physical activity, with an overall reduction in physical activity. Two other studies used retrospective reports of physical activity among university students and staff in Ohio and West Virginia from pre-pandemic to May–August 2020. Barkley et al. found reductions in mild physical activity among highly active individuals. However, the low-activity group increased in physical activity. They utilized the Godin

questionnaire and, again, could not examine specific domains of physical activity.[11] Olfert et al. found declines in physical activity using retrospective reports on the short form IPAQ.[13] Specifically, they found moderate physical activity increased, but the overall percentage of participants with low physical activity increased from 28% to 52% of respondents. One study by Maher et al. prospectively assessed the physical activity and sleep of undergraduates at a southeastern university in early 2020 and then again in April to May 2020 using similar measures to the current study, i.e., physical activity using the IPAQ short form and sleep quality using PSQI.[9] They found overall declines in MVPA and sleep quality on the PSQI, with scores increasing from 4.4 to 5.8 on the PSQI. While they found overall decreases in physical activity, they could not discern which domains were most affected using the IPAQ short form, which only assesses walking and moderate and vigorous physical activity as a whole. Interestingly, the current study found similar PSQI scores (5.9) even one year after the stay-at-home orders. Previous studies of changes in sleep among undergraduate students have used retrospective reporting,[9,22,43] and studies using devices to measure sleep have only measured sleep at a single timepoint.[44–46]

Overall, previous studies using perceptions, retrospective reporting, and self-reported behaviors early in the pandemic found declines in physical activity. However, none of these had device-measured physical activity or sleep or assessed self-reported physical activity across multiple domains, which, in the current study, we found different measures of behaviors to differ in their findings. While participants reported perceived declines in physical activity, both self-reported physical activity and device-measured physical activity and sleep did not change. Individuals may perceive different domains of physical activity differently, such that changes to active transport, e.g., walking to work, may have a greater influence on overall perceptions of physical activity. In contrast individuals may be less conscious of increases in other domains, such as domestic physical activity.

While perceived physical activity decreased, there were minimal changes in both self-reported and device-measured physical activity. This discrepancy may be important for health behavior interventions. Individuals may not accurately perceive current levels of physical activity. Behavioral change techniques, such as feedback,[47] using validated questionnaires or device tracking, may help individuals to understand their movement behaviors better. While devices can give a valid measure of total movement, it is important to combine them with context-specific assessment that measures physical activity across domains. Physical activity behaviors, rather than movement,[48] are more tangible to alter within the scope of habits and lifestyle routines.

It is important to note that the small sample size limited this study. While advanced statistical methods used all available data, we could not examine stratified analyses of specific populations. Previous research suggests that certain sub-populations were disproportionately affected by the pandemic.[49,50] For example, highly active individuals may have been more likely to maintain physical activity during lockdowns, while low-active individuals decreased physical activity even more.[49] Similarly, less active individuals were found to have a higher risk of mental health symptoms in response to the pandemic.[50] Larger, diverse samples are needed to better understand the differential impact of stressors on health behaviors to promote equitable interventions and policies.

5. Conclusion

This study found differential changes in physical activity and sleep from prior to the COVID-19 pandemic to mid-2021 among university students and staff depending on how the behaviors were assessed. While we found no changes in overall self-reported physical activity or device-measured physical activity or sleep, we found declines in self-reported sleep quality, declines in active transport physical activity, and increases in domestic physical activity. Physical activity and sleep are complex movement behaviors that are unlikely to change universally among a population, even in response to a major event such as a worldwide pandemic. Future studies may benefit from nuanced, multi-measure approaches that account for perceptions, domains, and device-measured changes in behaviors to better understand dynamic behavioral patterns.

Ethical approval statement

The study was approved by the University of Arkansas Institutional Review Board (IRB Protocol# 1808138910), and all participants provided written, informed consent.

Submission statement

All authors have read and agree with manuscript content and while this manuscript is being reviewed for this journal, the manuscript will not be submitted elsewhere for review and publication.

CRediT authorship contribution statement

Bryce T. Daniels: Writing – review & editing, Project administration, Investigation. **Samantha Robinson:** Writing – review & editing, Funding acquisition, Formal analysis, Conceptualization. **Ivan Vargas:** Writing – review & editing, Funding acquisition, Conceptualization. **Jamie I. Baum:** Writing – review & editing, Funding acquisition, Conceptualization. **Erin K. Howie:** Writing – original draft, Funding acquisition, Data curation, Conceptualization.

Conflict of interest

This study was funded by the University of Arkansas Provost Collaborative Grant. The authors declare no known conflicts of interest.

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