

Using a daily diary approach to examine the early effects of COVID-19 on daily physical activity bouts and contexts among residents of Colorado and California

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Abstract

COVID-19 restrictions may prevent adults from achieving sufficient physical activity (PA) and may affect PA context. This study examined the early effects of COVID-19 on daily PA bouts and contexts during April–June 2020 using a daily diary approach. Adults ($N = 390$) completed daily diary surveys for 28 days assessing number of PA bouts and social (e.g., alone), locational (i.e., home, neighborhood, recreational space), and technology (e.g., using streaming videos) contexts of PA. Mixed-effects models examined the effects of days since the pandemic started (on 3/13/2020), state residence, and demographics on number of daily PA bouts. Models examined demographic and temporal effects on PA context. Participants were 18–77 years, 15% Hispanic/Latino, and 80% female. PA bouts per day decreased significantly over time among Californians versus Coloradans ($b_{\text{simple}} = -0.01, p < .001$) and Hispanics/Latinos (vs. non-Hispanic Latinos) did fewer PA bouts per day ($b = -0.17, p = .04$). Most PA bouts occurred while alone (56.7%), at home (43.4%), or in any neighborhood (40.5%). Older (60+ years) versus younger (<40 years) adults were less likely to do PA with others (odds ratio [OR] = 0.40, 95% confidence interval [CI]: 0.18–0.90). PA bouts in recreational spaces were more common on weekends versus weekdays (OR = 1.59, 95% CI: 1.32–1.92) and were less common among California versus Colorado residents (OR = 0.23, 95% CI: 0.12–0.42). PA bouts decreased from April to June 2020, and these changes disparately affected subgroups. Resources are needed to counteract the negative effects of COVID-19 restrictions intended to slow disease spread on PA.

Keywords

Physical activity, Ecological Momentary Assessment, COVID-19, Time, Social environment

INTRODUCTION

The World Health Organization declared the COVID-19 respiratory disease caused by the SARS-CoV-2 virus a pandemic in March 11, 2020, after which the USA declared a national emergency on March 13, 2020. Following these declarations, state governments issued “Stay-at-home” or “Shelter-in-place” orders between March 19 and April 3, 2020. These orders typically required “non-essential” businesses to shift to remote operations, discouraged individuals from non-essential travel, and recommended maintaining social distancing of at least 6 feet with people outside of one’s own home [1, 2].

Implications

Practice: Individuals and health professionals should consider how COVID-19 restrictions may limit their access to recreational physical activity (PA) spaces and proactively plan how to maintain PA participation despite these restrictions.

Policy: Public health policymakers should be aware of the disparate, negative effects of COVID-19-related restrictions on PA participation and should consider the feasibility of approaches to support PA that benefit all subgroups of the population, as well as considering easing restrictions on access to outdoor recreational spaces while maintaining protection against disease spread.

Research: The study suggests that greater COVID-19-related restrictions in California versus Colorado affected the context and number of daily PA across time, with fewer bouts per day across time and fewer bouts in recreational spaces among residents of California.

Lay summary

The COVID-19 pandemic has resulted in closure of spaces for engaging in physical activity, including gyms, parks, and recreation centers. Closure of these spaces likely had a negative impact on activity. We used daily, phone-based surveys to study the effects of COVID-19 on the number of activity bouts individuals did each day, and the context of activity, between April and June 2020. Our study included 390 adults living in California or Colorado who were 18–77 years old, 80% female, and 15% Hispanic/Latino. Californians significantly decreased the number of daily bouts over time, but Coloradans showed no change in daily bouts. Hispanic/Latinos did fewer daily bouts than non-Hispanic/Latinos. Most bouts occurred when people were alone (56.7%), at home (43.4%), or in a neighborhood (40.5%). Adults 60+ years were more likely to do activity alone than with others. Bouts in recreational spaces were more common on weekends versus weekdays, and Californians were less likely to do bouts in recreational spaces than Coloradans. Additional resources are needed to counteract the negative effects of COVID-19 restrictions that intended to slow disease on activity levels, particularly in places with greater restrictions for accessing physical activity spaces.

Gyms, public parks, trails, and beaches were also closed starting in mid-March [1, 2]. In the state of Colorado, “Stay-at-home” orders were replaced by “Safer-at-home” orders on April 27, 2020, which stayed in effect through June 5, 2020. The guidelines for these “Safer-at-home” orders were very similar to the “Stay-at-home” orders, requiring individuals to “stay in your place of residence as much as possible and avoid unnecessary social interactions” [1, 3]. Colorado gyms and fitness centers remained closed until the beginning of June 2020, and residents were instructed to travel no more than 10 miles for outdoor recreation, with many Colorado mountain towns (common areas where Colorado residents engage in outdoor recreation) enacting fines of up to \$5,000 for the purpose of discouraging out-of-town visitors [1, 3–5]. The state of California, and Los Angeles County in particular, issued more restrictive “Safer-at-home” orders than Colorado and extended those orders through August 2020 [2, 6]. California gyms and fitness centers remained closed until June 12, 2020, and parks and playgrounds remained closed until September 2020 [7, 8].

While the COVID-19-related “Safer-at-home” orders, social distancing measures, and closures of activity spaces issued in states like California and Colorado were necessary to slow disease spread, they also had the potential to create barriers to individuals’ ability to engage in sufficient physical activity (PA). This detrimental impact is concerning given that greater physical fitness corresponds with an increased ability to respond to infections, counteract comorbidities that increase susceptibility to severe COVID-19 symptoms (e.g., obesity, hypertension), and protect against COVID-19 complications [9–11]. More than 70 million Americans used gyms and fitness centers in 2019 [12], suggesting that closure of these centers from March to June 2020 likely impacted PA. Parks also support PA participation, with 14%–40% of people using parks for exercise [13–15] and 25%–62% of PA occurring outdoors [15, 16], suggesting that restricting access to these activity spaces, through official orders in Colorado or continued closures in California (until September 2020), may have affected the amount and context of PA participation during the early months of COVID-19. “Safer-at-home” orders limiting travel outside of the home to “essential” tasks could also reduce incidental PA associated with going to grocery stores, running errands, or active transportation (e.g., walking to work or public transit). For example, preliminary research on the effects of COVID-19 restrictions during March–April 2020 found that PA among US adults decreased by 18%–48% [17–20], the majority of PA occurred at home or in a neighborhood [17], and trips to grocery stores and public transit stations decreased by 13% and 37%, respectively [21].

COVID-19 restrictions also had the potential to impact the social context of PA through the

combination of “Safer-at-home” orders, social distancing guidelines, and closures of activity spaces. Previous research indicates that interpersonal relationships impact PA participation, such that having social support for PA from friends or family increases PA participation [22]. Social isolation also negatively impacts total PA participation, with increased social isolation reducing PA participation [23, 24]. Prior to the COVID-19 pandemic, 37%–53% of PA bouts occurred while alone; whereas, the remainder of PA bouts occurred with other people, including 15%–25% of bouts occurring with friends, acquaintances, or coworkers [15, 16]. Data from the COVID-19 Social Study in the UK indicate that, during the first 2 months of the pandemic, 90% of individuals did not spend any time with friends, neighbors, or nonresident family members. The same study also found that high social support increased the odds of sustaining PA during the pandemic by 39% [25], indicating the potential for COVID-19 restrictions to impact the social context of PA due to effects on social isolation, social support, and the amount of time spent with friends, acquaintances, and others.

The goal of the current study was to investigate the effects of the COVID-19 pandemic on the number and context of daily PA bouts among US adults during April–June 2020 using a daily diary approach for capturing PA data. Using a daily diary approach to examine the effects of COVID-19 restrictions on PA provides an added benefit over previous research by allowing researchers to examine how PA levels might change or fluctuate on a day-to-day basis during the pandemic [26–28]. This approach also reduces the risk for recall biases and increases the ecological validity of findings [27–29], which is particularly important when considering the rapid changes in public health guidelines during the early months of the COVID-19 pandemic.

The first objective was to determine whether the number of daily PA bouts changed over 28 days during the early months of the pandemic. We hypothesized that number of daily PA bouts would decrease over time. Given the differences between states like Colorado and California in the severity and timing of “Safer-at-home” orders, social distancing guidelines, and closures of gyms, fitness centers, parks, etc. [1–8], as well as preliminary data indicating that adherence to social distancing guidelines differs by population density and geographic location [21], we also sought to examine whether changes in daily PA bouts differed by state residence. We hypothesized that the more severe COVID-19 restrictions in California would correspond with California residents engaging in fewer PA bouts per day. The second objective was to examine the effects of demographic and temporal factors on the context of PA bouts such as social settings and locations. We hypothesized that a larger proportion of PA bouts would occur while

alone versus with others, and that a larger proportion of PA bouts would occur either at home or in neighborhoods versus in recreational spaces. Finally, we examine the use of technology to facilitate PA, such as doing PA remotely with friends/family, the use of live streaming fitness classes, etc., since exercise professionals have promoted the use of technology for supporting home-based exercise during the pandemic [20, 30]. We hypothesized that participants would use technology to facilitate PA participation, but that the majority of PA bouts would still occur without the use of technology. Given the potential for exercise to protect against risk for and complications of COVID-19 [9–11] and concerns that short-term lapses in PA could result in long-term disengagement in PA [31], understanding the effects of the COVID-19 pandemic on PA participation is a public health concern.

METHODS

Study design

This study assessed the effects of the COVID-19 pandemic on levels and contexts of PA participation among US adults through daily, smartphone-based surveys completed over 28 consecutive days between April 10 and June 9, 2020.

Recruitment and participants

We recruited a convenience sample of adults living in the USA during the COVID-19 pandemic via social media platforms (e.g., Facebook, Twitter, LinkedIn) and university-based list serves. We recruited participants from two sites—Colorado State University (CSU) and University of Southern California (USC). Inclusion criteria included: 18 years or older, able to speak and read English, live in the USA, and own and regularly use an Android or iPhone smartphone that they are willing to use to complete app-based surveys. Exclusion criteria included enrollment in another study related to PA, including studies monitoring or intervening on PA, examining the effects of wearable fitness trackers on PA, etc. The Institutional Review Boards of CSU (Protocol #20-9987H) and USC (Protocol # HS-20-00304) determined that the study procedures were no more than minimal risk and approved the study as exempt from full review.

Procedures

Participants consented to participate and completed a baseline, electronic survey between March 30 and May 25, 2020, after most US states issued “Shelter-in-place” or “Stay-at-home” orders. The survey required approximately 30 min to complete. After completing the baseline survey, participants completed a 28-day daily diary protocol during the early months of the pandemic (April 3–June 17, 2020). CSU and USC participants used the Illumiv

EMA and RealLife Exp app (by LifeData), respectively, downloaded to their personal Android or Apple smartphones to complete the daily diary protocol. Participants received two surveys per day, one in the morning (8 am/9 am for USC/CSU) and one in the evening (7 pm/8 pm for USC/CSU). Each survey took up to 3 min to complete. Participants who did not respond to the initial survey notification received up to two reminders (45-/5-min intervals for USC/CSU) to complete the survey. Participants were given 2 hr to answer each survey, with the morning survey available from 8 am to 10 am and the evening survey available from 7 pm to 9 pm. Only data from evening survey prompts were included in the present analyses. USC participants who completed the baseline survey were entered into a lottery to win one of ten \$50 gift cards. USC participants were not compensated for completing the daily diary protocol. CSU participants were not compensated for completing the baseline survey or daily diary protocol.

Measures

Self-reported PA

Participants reported their daily PA during the evening survey [29]. Participants were asked: “Did you do PA for at least 10 minutes at least one time today?” with response options of “Yes” or “No.” Participants who reported one PA bout were asked if they completed additional bouts, using the same question described above. Participants were able to report up to three PA bouts per day. For the analyses, the total number PA bouts per day that were at least 10 min long was used as the primary outcome variable in subsequent analyses.

Social contexts of PA

Participants reported social context for each PA bout including whether they did activity alone or with others. Response options ranged from “0–Did activity alone” to “6 or more other people.” Social context was recoded into a dichotomous outcome variable for subsequent analyses: 0–Did activity alone versus 1–Did activity with others.

Locational contexts of PA

Participants reported the location of each PA bout with response options including: “Inside my home,” “Outside of my home,” “In my neighborhood,” “In another neighborhood,” “In an outdoor recreational space, like a park, trail system, etc.,” and “In an indoor recreational space, like a gym, pool, etc.” Locational context was recoded into three dichotomous outcome variables for subsequent analyses: (a) Home: 0–Not at home versus 1–At home, (b) Neighborhood: 0–Not in a neighborhood versus 1–In any neighborhood, and (c) Recreational Space: 0–Not in a recreational space versus 1–In a recreational space.

Use of technology to facilitate PA

Participants reported the use of technology or streaming services for each PA bout in response to the question “*Did you use any remote/streaming services to facilitate your physical activity?*” with response options including: “*Yes—I did physical activity remotely with friends or family,*” “*Yes—I streamed live classes from my gym/fitness facility,*” “*Yes—I streamed workout classes (live or recorded) from a website, YouTube video, smartphone app, etc.,*” and “*No—I did not use any remote/streaming services.*” Use of technology/streaming services was recoded into a dichotomous outcome variable for subsequent analyses: 0—*Did not use technology/streaming services* versus 1—*Used technology/streaming services.*

All daily diary survey items included a response option of “*Do not know/Prefer not to answer*” which was recoded as missing.

Demographics

Participants self-reported age in years, biological sex (male or female), ethnicity (non-Hispanic/Latino or Hispanic/Latino), race (check all that apply: American Indian/Alaska Native, Asian, Native Hawaiian/Pacific Islander, Black, White, or other), education (12th grade or less, high school graduate/GED, some college/technical school/Associate’s degree, Bachelor’s degree, or graduate degree), current school status (later categorized as not in school, in school), employment status (later categorized as employed full-time, employed part-time, or unemployed/disabled/retired), and household income (later categorized as <\$27,000/year, \$27,000–59,999/year, \$60,000–99,999/year, or ≥\$100,000/year). Participants self-reported height (in feet and inches) and weight (in pounds), which was used to calculate body mass index (BMI). BMI was categorized as underweight (<18.5 kg/m²), normal weight (18.5–24.9 kg/m²), overweight (25.0–29.9 kg/m²), and obese (≥30.0 kg/m²).

Statistical analyses

Data from CSU and USC were combined prior to analyses. A total of 501 participants ([CSU: n=286, USC: n=215]; n = 286, USC: n = 215) responded to at least one daily diary survey; however, to examine the potential effects of state residence on PA bouts, only participants residing in either Colorado (n = 265) or California (n = 125) were included, resulting in a final analytic sample of 390 participants. Multilevel linear regression models with days nested in participants examined the main effects of time (number of days) since the COVID-19 National Emergency was declared in the USA (March 13, 2020), state residence (Colorado vs. California), and the interaction between time and state residence, on total PA bouts per day. All models were adjusted for age, sex, ethnicity, income, work status, BMI, day of week (weekday vs. weekend), and the date the participant started the 28 days of daily diary surveys.

Race was not included due to multicollinearity with ethnicity. Models were tested to determine whether to include random effects of time or state residence.

Multilevel logistic regression models with bouts nested in participants tested whether demographic (i.e., age, sex, ethnicity, income, work status, BMI, and state residence) or temporal (i.e., day of week, time since COVID-19 emergency) factors predicted the odds of a PA bout occurring in each social, locational, and technology/streaming service context. The effects of demographic and temporal patterns are described using odds ratios (ORs) and predicted marginal proportions. All analyses were conducted in R version 4.0.0 [32], and statistical significance was set at $p < .05$.

RESULTS

There were 10,214 day-level daily diary evening observations, with participants responding to 6,614 prompts (64.8%). Multilevel logistic regression models indicated that California residents were more likely to respond to evening surveys than Colorado residents (OR = 1.68, 95% confidence interval [CI] = [1.01–2.79]). Participants were less likely to respond on weekends than weekdays (OR = 0.86, 95% CI = [0.76–0.96]). There were no effects of age, sex, ethnicity, income, work status, or weight status on the odds of responding to evening surveys.

The final analytic sample was 80.0% female, 84.6% non-Hispanic, and 82.6% White, with a mean age of 35 ± 12.9 years. Table 1 summarizes the demographic characteristics for the final sample and by state residence. Table 2 summarizes the descriptive statistics for number and context of daily PA bouts. Participants engaged in at least one PA bout per day on 70% of days (n = 4,609 days) and reported a total of 6,879 PA bouts across the study period. Participants reported engaging in one, two, or three PA bouts per day on 60%, 32%, and 8% of the days they engaged in PA, respectively, averaging 0.9 ± 0.9 PA bouts per day. Participants engaged in 40.3% of bouts with other people. 43.4% of bouts occurred in participants’ homes, and 18.1% involved the use of technology/streaming services.

PA bouts per day

Table 3 shows the multilevel linear model outcomes testing the effects of time, state residence, and the moderation of time by state residence on number of PA bouts per day. Main effects models showed significant effects of time ($b = -0.005$, $p < .001$) and living in California (vs. Colorado; $b = -0.35$, $p < .001$) on number of daily PA bouts. Moderation analyses revealed a significant time by state residence interaction ($b = -0.01$, $p < .001$). As shown in Fig. 1, California residents demonstrated significant decreases in PA bouts across time (simple slope: $b = -0.01$, $p < .001$); whereas,

Table 1 | Participant demographics for final sample and by state residence

Demographics	Final sample (N = 390)	California (N = 125; 32.5%)	Colorado (N = 265; 67.9%)
Age in years (mean ± SD)	35.3 ± 12.9	31.5 ± 11.2	37.1 ± 12.9*
Age category (n (%))			
<40 years	282 (72.3)	104 (83.2)	178 (67.2)*
40–59 years	76 (19.5)	17 (13.6)	59 (22.3)*
60+ years	32 (8.2)	4 (3.2)	28 (10.4)*
Sex (n (%))			
Male	77 (19.7)	20 (16.0)	57 (21.5)*
Female	312 (80.0)	105 (84.0)	207 (78.1)*
Missing	1 (0.3)	0 (0.0)	1 (0.4)
Ethnicity (n (%))			
Non-Hispanic	330 (84.6)	90 (72.0)	240 (90.6)*
Hispanic	57 (14.6)	34 (27.2)	23 (8.7)*
Missing	3 (0.8)	1 (0.8)	2 (0.8)
Race (n (%))			
White	322 (82.6)	80 (64.0)	242 (91.3)*
Asian	26 (6.7)	21 (16.8)	5 (1.9)*
Black	6 (1.5)	4 (3.2)	2 (0.8)*
American Indian/Alaska Native	2 (0.5)	0 (0.0)	2 (0.8)
Native Hawaiian/Pacific Islander	2 (0.5)	1 (0.8)	1 (0.4)
Mixed Race	18 (4.6)	8 (6.4)	10 (3.8)*
Other Race ^a	11 (2.8)	9 (7.2)	2 (0.8)*
Missing	3 (0.8)	2 (1.6)	1 (0.4)
Education (n (%))			
High school or less	6 (1.5)	4 (3.2)	2 (0.8)
Some college education or more	383 (98.2)	121 (96.8)	262 (98.9)
Missing	1 (0.3)	0 (0.0)	1 (0.4)
Current school status (n (%))			
Not in school	215 (55.1)	60 (48.0)	155 (58.5)
In school	175 (44.9)	65 (52.0)	110 (41.5)
Work status (n (%))			
Full-time	240 (61.5)	62 (49.6)	178 (67.2)*
Part-time	107 (27.4)	32 (25.6)	75 (28.3)
Unemployed/Disabled/Retired	41 (10.5)	30 (24.0)	11 (4.2)*
Missing	2 (0.5)	1 (0.8)	1 (0.4)
Income (n (%))			
<\$27,000/year	54 (13.8)	15 (12.0)	39 (14.7)
\$27,000–59,999/year	121 (31.0)	37 (29.6)	84 (31.7)
\$60,000–99,999/year	78 (20.0)	20 (16.0)	58 (21.9)*
≥\$100,000/year	121 (31.0)	45 (36.0)	76 (28.7)*
Missing	16 (4.1)	8 (6.4)	8 (3.0)

*Significant differences between California and Colorado samples. Differences were tested using *t*-tests for continuous variables and chi-square tests for categorical variables.

Colorado residents showed no change in PA bouts over time (simple slope: $b = -0.002$, $p = .26$). Adults identifying as Hispanic/Latino engaged in fewer PA bouts per day than those who did not identify as Hispanic/Latino ($b = -0.18$, $p = .03$), and individuals earning \$60,000–99,999/year ($b = 0.28$, $p = .01$) and ≥\$100,000/year ($b = 0.29$, $p = .004$) engaged in more PA bouts than individuals earning <\$27,000/year.

Social contexts of activity bouts

The majority of PA bouts occurred alone (57%). The proportion of bouts occurring with others decreased with age, with a 20% difference between individuals younger than 40 years versus 60+ years (OR = 0.40, 95% CI = [0.18–0.90]). The proportion of bouts occurring with others decreased with higher income, with a 17% difference between low/middle (\$27,000–59,999/year) versus high-income

Table 2 | Social context, locational context, and use of technology/streaming services for physical activity bouts

Variable	Final sample (N = 390)	California (N = 125; 32.5%)	Colorado (N = 265; 67.9%)
Physical activity (PA)			
Total PA bouts	6,879	1,804	5,075
Bouts per day (mean \pm SD)	0.9 \pm 0.9	0.7 \pm 0.8	1.1 \pm 0.9*
Social context (n (%))			
Did PA alone	3,899 (56.7)	1,055 (58.5)	2,844 (56.0)
Did PA with others	2,769 (40.3)	736 (40.8)	2,033 (40.1)
Missing	211 (3.1)	13 (0.7)	198 (3.9)
Locational context (n (%))			
PA in home	2,984 (43.4)	821 (45.5)	2,163 (42.6)
PA in neighborhood	2,785 (40.5)	854 (47.3)	1,931 (38.0)*
PA in recreational space	901 (13.1)	115 (6.4)	786 (15.5)*
Missing	209 (3.0)	14 (0.8)	195 (3.8)
Technology/streaming services (n (%))			
Did not use technology/streaming services	5,449 (79.2)	1,393 (77.2)	4,056 (79.9)
Used technology/streaming services	1,245 (18.1)	406 (22.5)	839 (16.5)*
Missing	185 (2.7)	5 (0.3)	180 (3.5)

*Significant differences between California and Colorado samples. Differences were tested using t-tests for continuous variables and chi-square tests for categorical variables.

individuals (\geq \$100,000/year; OR = 2.07, 95% CI = [1.24–3.48]). A larger proportion of bouts occurred with others among individuals who worked part-time versus full-time (OR = 1.60, 95% CI = [1.02–2.52]), with an 11% difference between the two. The other demographic factors, including sex, ethnicity, work status, BMI category, and state residence, were not associated with the social context of PA bouts. Participants were more likely to do PA with others on weekends than weekdays (OR = 1.79, 95% CI = [1.56–2.06]), with a 14% difference between the two. Time (in days) since the COVID-19 emergency was not associated with the social context of PA bouts.

Locational context of activity bouts

The majority of PA bouts occurred at home (43.4%) or in any neighborhood (40.5%). A larger proportion of bouts occurred at home among individuals who worked part-time versus full-time (OR = 1.84, 95% CI = [1.21–2.81]), with a 15% difference between the two. The other demographic factors, including age, sex, ethnicity, income, BMI category, and state residence, were not associated with engaging in PA at home. The proportion of bouts occurring at home decreased over time (OR = 0.99, 95% CI = [0.99–1.00]), with, for example, 46% and 33% occurring at home 30 and 90 days after March 13, 2020, respectively. Day of the week (weekend vs. weekday) was not associated with engaging in PA bouts at home.

The proportion of bouts occurring in any neighborhood was greater among overweight versus normal weight individuals (OR = 1.52, 95% CI = [1.01–2.30]), with a 5% difference between the two. A larger proportion of bouts occurred in neighborhoods among individuals living in California

versus Colorado (OR = 1.93, 95% CI = [1.26–2.98]), with a 16% difference between the two. The other demographic factors, including age, sex, ethnicity, income, and work status, were not associated with engaging in PA in any neighborhood. Day of the week and time (in days) since the COVID-19 emergency were not associated with engaging in PA in any neighborhood.

A smaller proportion of bouts occurred in a recreational space among individuals working part-time versus full-time (OR = 0.55, 95% CI = [0.32–0.95]), with a 3% difference between the two. A smaller proportion of bouts occurred in recreational spaces among individuals living in California versus Colorado (OR = 0.23, 95% CI = [0.12–0.42]), with an 8% difference between the two. The other demographic factors, including age, sex, ethnicity, income, and BMI category, were not associated with engaging in PA bouts in a recreational space. Doing PA in a recreational space was more likely on weekends than weekdays (OR = 1.59, 95% CI = [1.32–1.92]), with a 3% difference between the two. The proportion of bouts occurring in a recreational space increased over time (OR = 1.01, 95% CI = [1.00–1.02]), with 6% and 15% occurring in a recreational space 30 and 90 days after March 13, 2020, respectively. [Figure 2](#) shows the effect of time (in days) since the COVID-19 emergency on the locational context of PA bouts.

Technology/streaming service context of activity bouts

The majority of PA bouts (79%) occurred without using technology/streaming services. Females used technology/streaming services for a larger proportion of PA bouts than males (OR = 3.51, 95% CI = [1.75–7.04]), with a 9% difference between the

Table 3 | Multilevel models with time and state residence predicting physical activity bouts per day

Models	Physical activity bouts per day ^a	
	<i>b</i> (SE)	<i>p</i>
Intercept	0.97 (0.15)	<.001
Age ^b		
40–59 years	0.04 (0.08)	.58
60+ years	0.13 (0.12)	.29
Female	–0.04 (0.07)	.62
Hispanic/Latino	–0.18 (0.09)	.03
Income ^c		
\$27,000–59,999/year	0.13 (0.09)	.18
\$60,000–99,999/year	0.28 (0.11)	.01
≥\$100,000/year	0.29 (0.10)	.004
Work status ^d		
Part-time	0.07 (0.07)	.30
Unemployed/disabled/retired	–0.02 (0.11)	.88
BMI category ^e		
Underweight	0.09 (0.22)	.77
Overweight	–0.20 (0.07)	.003
Obese	–0.41 (0.09)	<.001
Weekend ^f	–0.08 (0.02)	<.001
Survey start date	0.004 (0.004)	.28
Time ^g	–0.002 (0.002)	.29
California resident	0.08 (0.14)	.56
Time × California resident	–0.01 (0.003)	<.001
Intercept only ICCs		
Within-person level		0.58
Between-person level		0.32

BMI body mass index; ICC intraclass correlation coefficient.

^aModel included 6,925 days nested in 362 participants. A random effect for time was included at the participant level.

^bReference group: <40 years of age.

^cReference group: <\$27,000/year.

^dReference group: full-time.

^eReference group: normal weight.

^fReference: weekday.

^gZero value for time set at March 13, 2020—the date on which COVID-19 was declared a National Emergency in the USA.

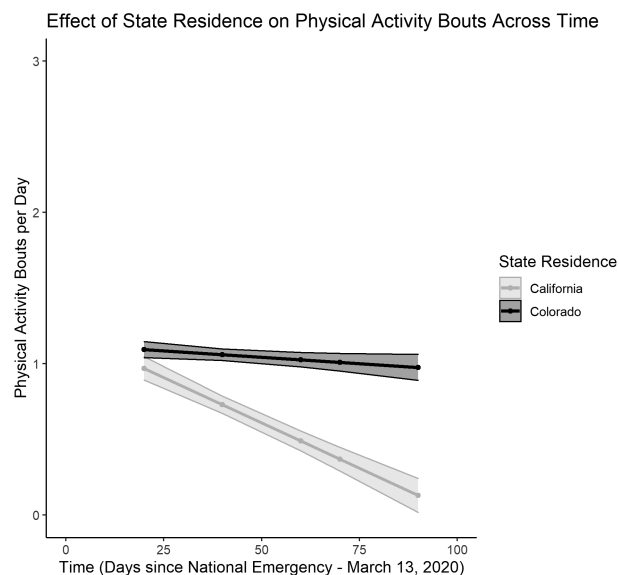


Fig 1 | Effect of state residence on physical activity bouts across time.

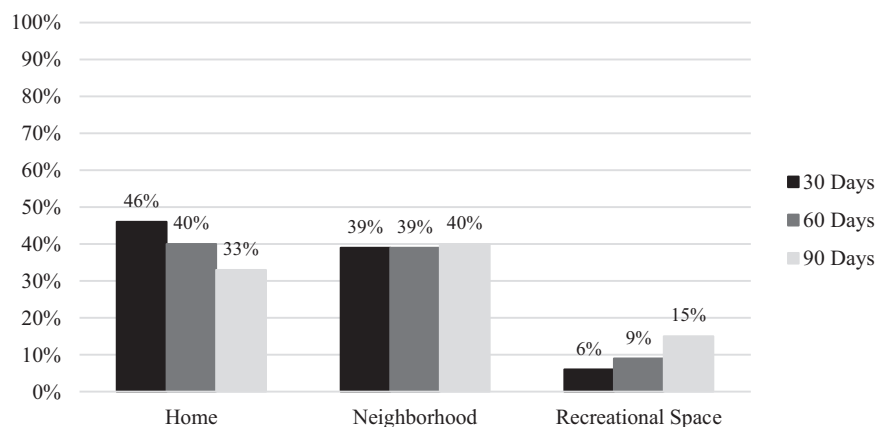


Fig 2 | Effect of time since national emergency on locational context of physical activity bouts.

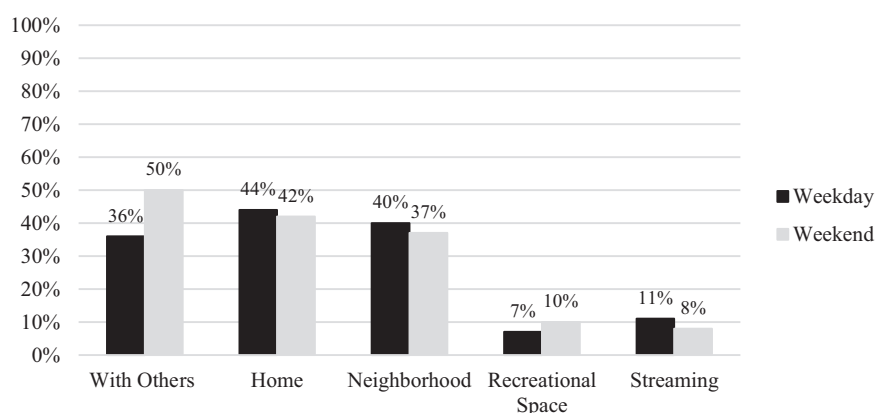


Fig 3 | Effect of day of week on social, locational, and streaming context of physical activity bouts.

two. The other demographic factors, including age, ethnicity, income, work status, BMI category, and state residence, were not associated with using technology to facilitate PA. Doing PA using technology/streaming services was less likely on weekends than weekdays (OR = 0.67, 95% CI = [0.56–0.81]), with a 3% difference between the two. Time (in days) since the COVID-19 emergency was not associated with using technology to facilitate PA. Figure 3 shows the effect of day of week on the social, locational, and technology/streaming service context of PA bouts.

DISCUSSION

This study used a daily diary approach to examine changes in PA levels and the effects of demographic and temporal factors on the contexts of PA bouts from April to June 2020 during the COVID-19 pandemic among adults living in Colorado and California. The number of PA bouts per day decreased significantly over time among California, but not Colorado, residents. This decrease in PA bouts per day among California and Colorado residents corresponds with other studies among US adults finding that PA decreased 18%–48% from late March to early April 2020 [17–20]. The majority

European and Asian countries also found decreases in PA during the early months of COVID-19 [33–35], although some countries did not demonstrate decreases in PA [36, 37].

We found that the majority of activity bouts occurred at home or in a neighborhood, with only 13% of bouts occurring in recreational spaces. This was lower than prepandemic research indicating that 25%–62% of activity bouts occur in recreational/outdoors spaces [15, 16], which is likely due to the closure of recreational spaces (e.g., gyms, parks) at the beginning of the pandemic [1–8]. As time elapsed, the proportion of bouts occurring at home decreased, corresponding with an increasing proportion of bouts occurring in recreational spaces. This change in activity contexts over time may reflect greater access to recreational spaces later in the study period, particularly among Colorado residents [5]. The greater use of recreational spaces over time is important because using parks and green spaces confers physical and psychological health benefits that could help mitigate pandemic-related increases in stress and anxiety [21, 38, 39].

State residence also affected the locational context of PA bouts and the number of PA bouts per day over time. California residents engaged in fewer

PA bouts over time and were more likely to engage in activity in neighborhoods, and less likely to engage in activity in recreational spaces, compared with Colorado residents. Although California and Colorado issued similar stay-at-home and social distancing orders and closed gyms during the early days of the pandemic, Colorado parks and trails remained open during this timeframe [1, 5]; whereas, California closed recreational spaces, including parks, beaches, and trails, many of which remained closed until September 2020 [2, 8]. Additionally, California has fewer parks per capita than Colorado [40]. California's closures of recreational spaces and lesser access to parks could help account for the California residents in our study engaging in fewer PA bouts over time, more PA bouts in neighborhoods, and fewer PA bouts in recreational spaces. The greater population density of California [41] may have also increased Californians' awareness of the severity of the pandemic and their likelihood of engaging in social distancing compared with Coloradans [21]. This greater awareness and adherence to social distancing guidelines may have encouraged California residents to abide more closely to Stay-at-home orders by engaging in activity in their neighborhoods, rather than recreational spaces.

Across the April–June study period, 56.7% of PA bouts occurred while alone, which is similar to, or higher than, prepandemic levels, depending on the study in question, with prepandemic data indicating that 37%–53% of PA bouts occurred while alone [15, 16]. Individuals were also more likely to engage in activity with others and to use recreational spaces for activity on weekends versus weekdays, a finding that corresponds with previous studies [16]. These effects of day of the week on activity context suggest that weekends afford greater opportunities for engaging in activity in social and recreational settings, likely due to greater free-time. While unsurprising, these findings give some cause for concern given surges in COVID-19 cases during periods of greater free-time, such as holidays (i.e., Memorial Day, Independence Day) [42, 43].

Demographic factors influenced social context of PA among California and Colorado residents. Older individuals (≥ 60 years) were more likely to engage in activity bouts alone, a finding that is similar to previous research [16]. Older adults doing PA alone could protect against infection, which is important given their increased risk for hospitalization and mortality if infected with COVID-19 [44]. Higher income individuals were more likely to do activity alone; however, they also engaged in more bouts of PA per day than lower income individuals. Additionally, adults who identified as Hispanic/Latino engaged in fewer PA bouts per day. These disparities by ethnicity and income could be related to decreases in transportation and occupation-related activity [21], and are concerning given

already-existing disparities in COVID-19 exposures and mortality rates among lower income and ethnic minorities [45–47].

Disparities in the frequency and volume of activity also prevent lower income and ethnic minority individuals from capitalizing on the protective effects of exercise for reducing risk for, and complications of, COVID-19 [9–11]. Overcoming these disparities is a challenge that some hoped would be achieved by using technology to support PA via fitness apps, live streaming, or prerecorded fitness classes [20, 30, 48]. At the beginning of the pandemic, many exercise professionals recommended using social media platforms, apps, or video conferencing to support home-based exercises [30], and the popular press asserted that COVID-19 was “transforming the fitness industry” due to rapid increases in the use of prerecorded and streaming classes following the onset of the pandemic [48]. Unfortunately, our findings suggest that the use of technology for activity was low among California and Colorado residents, with only 18% of activity bouts being facilitated by technology. Fitness industry professionals may have been overeager in their assessment of the potential for technology to make “wellness a lot more accessible” [48]. However, use of technology-based activity services has increased among individuals who were using pay-based fitness services prior to the pandemic. Among users of the wellness platform Mindbody, 73% and 85% accessed prerecorded or livestream classes in March 2020, versus 17% and 7% in 2019, respectively [48]. Additionally, increased frequency of using PA smartphone apps, particularly those with gamification features, buffered the negative effects of the pandemic on PA participation [20]. This suggests that technology may help those who already use pay-based fitness services, and that smartphone apps in particular may be more helpful than streaming videos or prerecorded fitness classes in overcoming common barriers, such as cost, to being active. Our findings and others suggest that the effect of technology for increasing accessibility and overcoming disparities in PA participation across all individuals may be limited.

Despite the limited use of technology in our sample, one intervention using YouTube videos successfully increased adults' intention to take more active breaks from sedentary time and decreased sedentary behavior by 20 min/day, indicating that technology could be helpful in overcoming some of the negative effects of the pandemic on movement-related behaviors [49]. Other approaches to overcoming COVID-19 restrictions to PA that do not rely on technology are also worth consideration. For example, *La Ruta de Movimiento* is a PA intervention created by the Ministry of Sport in Bogota, Colombia that uses roving fitness instructors to teach fitness classes to community members from a distance, with instructors teaching on the ground and community

members engaging in PA on their terraces, balconies, front gardens, etc. [50]. As such, PA experts and public health practitioners should consider the potential for technology- and nontechnology-based approaches for overcoming COVID-19 barriers to PA participation.

Strengths of this study include the use of a daily diary approach to collect data during the early months of the COVID-19 pandemic (April–June 2020) and the assessment of the context of activity bouts through daily diaries. There were some limitations. The PA measure used has not been validated. PA was not defined for participants in the daily diary surveys and the use of self-reported measures of PA introduced the possibility of recall biases and errors; however, this approach has previously been validated and is more accurate than traditional PA self-report methods [29] because daily diary measures shorten the timeframe for recall to the same day, rather than the previous week or month, reducing the risk for recall bias. Limiting participants to reporting no more than three PA bouts per day may have resulted in failing to capture all PA participation throughout the day. Differing response rates by state residence and day of the week could have affected model estimates. Our sample also consisted primarily of young, female, and well-educated individuals living in California and Colorado, limiting the generalizability of our findings. Future research examining the effects of the COVID-19 pandemic on PA participation and context should include larger, more representative samples and objective measures of PA and activity contexts to fully capture the impact of the pandemic on PA.

CONCLUSIONS

In summary, data from our daily diary surveys indicated that PA participation among California and Colorado residents decreased from April to June 2020 and the majority of activity bouts occurred at home or in a neighborhood. Differences in number of daily PA bouts by state residence could be due to California's closures of recreational spaces, their stricter social distancing guidelines, or greater adherence to social distancing guidelines related to the higher population density of California compared with Colorado. Differing effects of demographic factors, including ethnicity and income, on the context of activity and PA participation over time suggest disparate effects of COVID-19 among subgroups who are potentially vulnerable due to increased COVID-19 exposure and mortality rates. Minimal use of technology for supporting PA indicates that technology may be insufficient for overcoming pandemic-related barriers to PA. These findings highlight the need to develop PA resources, particularly for vulnerable populations, to help counteract the negative effects of COVID-19 on PA.

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COMPLIANCE WITH ETHICAL STANDARDS

Conflict of Interest: None declared.

Authors' Contributions: JC, KN, SW, BD, and GD designed the study and collected the data. JC, SW, and BD cleaned the data. JC analyzed the data. JC drafted the original manuscript. KN, SW, BD, and GD provided edits and feedback on the original manuscript draft.

Ethical Approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent: Informed consent was obtained from all individual participants included in the study.

Welfare of Animals: This article does not contain any studies with animals performed by any of the authors.

TRANSPARENCY STATEMENTS

- Study registration:** This study was not formally registered.
- Analytic plan preregistration:** The analysis plan was not formally preregistered.
- Data availability:** Deidentified data from this study are not available in a public archive. Deidentified data from this study will be made available (as allowable according to institutional IRB standards) by emailing the corresponding author.
- Analytic code availability:** Analytic code used to conduct the analyses presented in this study are not available in a public archive. They may be available by emailing the corresponding author.
- Materials availability:** Materials used to conduct the study are not publicly available. They may be available by emailing the corresponding author.

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