Early Effects of the COVID-19 Pandemic on Physical Activity Locations and Behaviors in Adults Living in the U.S.: Differences by Ethnicity and Income

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Abstract

Background: COVID-19 restrictions, social-distancing, and quarantining may inhibit adults from attaining recommended levels of physical activity.

Purpose: The aims were to examine the early impact of the COVID-19 pandemic on physical activity in adults during the first two months of restrictions in the U.S., and how physical activity locations were associated with physical activity levels during this same period.

Method: Adults (N = 268) completed an online survey between April 10-May 25, 2020. Participants reported minutes of vigorous, moderate, and walking physical activity for the past 7 days (early-COVID-19) and for a typical week in February 2020 (pre-COVID-19). Adults reported locations (e.g., home/garage, parks/trails) were they were active over the past 7 days. Past 12-month step count data were extracted from participants' personal smartphones.

Results: Participants (18-74 years old, 22% Hispanic/Latino, 81% female, 41% overweight/obese) showed reductions in vigorous (M_{diff}=-66.9 min/week), moderate (M_{diff}=-92.4 min/week), walking (M_{diff}-70.8 min/week), and step counts (M_{diff}=-2232 steps/day) from the pre- to early-COVID-19 periods. Reductions in walking and steps were larger for low-income and Hispanic/Latino adults. During early-COVID-19, more vigorous and moderate activity were reported by those who were active in their home/garage or driveway/yard, and more steps were recorded by those who were active on the roads in their neighborhood or at parks/trails.

Conclusion: Higher risk population sub-groups may be more affected by the COVID-19 pandemic in terms of its impact on health-related behaviors. Communication, programmatic, and policy efforts should be directed towards promoting home- and neighborhood-based physical activity during the COVID-19 pandemic.

Key words: vigorous activity; moderate activity; walking; step counts; income

Introduction

COVID-19, the respiratory disease caused by the SARS-CoV-2 virus, has been declared a pandemic by the World Health Organization and a national emergency in the United States of America (U.S.). Originating in Wuhan, China in late 2019, COVID-19 spread mainly among countries in Asia and Europe in February, and then widely throughout North America in March and April 2020. As of the date this article was written (July 13, 2020), there were 3.4 million COVID-19 cases and 138,000 related deaths recoded by the U.S. Centers for Disease Control and Prevention [1].

In order to limit the spread of COVID-19, state governments in the U.S. issued "Shelter-in-place" or "Stay-at-home" orders starting between March 19 – April 3, 2020 [2]. Although a few states rescinded or ended these orders in late April and early May, most states extended the expiration dates through May 15 – May 29, 2020. "Shelter-in-place" and "Stay-at-home" orders vary in scope from state to state but generally require "non-essential" businesses to close their physical offices or storefronts and continue their operations remotely. These guidelines require residents to remain at home except when performing essential activities including purchasing groceries and seeking medical treatment. In most states, local governments ordered all restaurants and bars to halt dine-in service, and for gyms/fitness facilities, theatres, bowling alleys, hair/nail salons, and other non-essential business to temporarily close. Orders do not completely prohibit people from leaving their homes, as residents are allowed to take walks and in outdoor spaces as long as they maintain social distancing of at least 6 feet away from people not in their households. Starting mid-March, schools closed in all 50 states with many states extending schools closures through the end of the 2019-2020 school year [3]. Federal, state, and local public parks, trails, and beaches were also closed in many jurisdictions starting mid-to-late

March with some re-openings occurring in late April and early May, and most others in early to late June.

Despite the public health necessity of these social-distancing measures in order to slow the spread of COVID-19 and ensure that medical facilities have adequate resources to address needs, they may impose restrictions on individuals' ability to engage in sufficient levels of physical activity in order to maintain health and prevent further disease. The Physical Activity Guidelines for Americans recommend that adults engage in at least 150 minutes of moderate-intensity or 75 minutes of vigorous-intensity physical activity per week to reduce risks of obesity, cancer, heart disease, diabetes, and other chronic conditions [4]. However, pre-pandemic levels of adherence to these guidelines were already less than desired for population health. According to estimates, approximately 65% of U.S. adults achieved these physical activity guidelines in 2015-2016 when assessed through self-report [5], and estimates of adherence to these guidelines may much lower when assessed through accelerometery [6]. Participation rates in physical activity are not equal across all segments of the populations, with lower levels of physical activity among Hispanic adults as compared to non-Hispanic adults, and among individuals from lower income households [5].

Restrictions and social-distancing measures introduced by the COVID-19 pandemic may inhibit U.S. adults from attaining recommended levels of physical activity [7 8]. More than 70 million Americans regularly access gyms and fitness facilities [9], indicating that closure of these businesses may have a profound effect on physical activity behaviors. Furthermore, restricted access to public parks, trails, and beaches may eliminate low- and no-cost opportunities for outdoor physical activity. Potentially, one of the more significant impacts on physical activity levels during the COVID-19 pandemic may be the changes in daily routines, habits, mobility,

and commuting patterns of U.S. adults. By limiting reasons to leave the house, incidental physical activity (e.g., during errands or chores) and active transportation (e.g., biking to work, walking to public transit) may decline dramatically. Preliminary data on the impact of COVID-19 restrictions suggests that physical activity among U.S. adults was reduced between 32% and 48% during the first week of April 2020 [10 11]. Although alternative forms of leisure-time physical activity, such as virtual fitness/exercise classes and neighborhood-based walking, have the potential to replace activity taking place at facilities that have been closed during the pandemic (e.g., gyms/fitness facilities, parks/trails), there may be enormous inequities in access to these opportunities based on sociodemographic and economic characteristics.

The overall goal of the current study was to investigate the early impact of the COVID-19 pandemic on activity levels among U.S. adults during the first full month that "Shelter-in-place" and "Stay-at-home" orders were in place. The primary objective was to determine whether levels of vigorous, moderate, and walking physical activity significantly declined from the pre-COVID-19 period (February 1-29, 2020) to the early-COVID-19 period (April 3 – May 25, 2020), and whether changes in physical activity levels differed by self-reported ethnicity (Hispanic/Latino vs. non-Hispanic/Latino) and household income. The secondary objective was to describe the locations of physical activity during the early-COVID-19 period and examine the extent to which physical activity locations were associated with physical activity levels during this same period. Given emerging evidence of the potential immune-protective effect of cardiorespiratory exercise against complications of COVID-19 [12] combined with concerns that temporary lapses in physical activity can extend to permanent disengagement with the behavior [13], understanding the early effects of the COVID-19 pandemic on physical activity levels in U.S. adults is an important public health issue.

Methods

Study Design

We adopted a prospective survey design to assess the early effects of the COVID-19 pandemic on physical activity among U.S. adults by using online surveys. A baseline survey was completed between April 10 – May 25, 2020, and a follow-up survey is scheduled to occur within 6-12 months. Following the baseline survey, some participants completed 28 subsequent days of mobile phone-based ecological momentary assessment with morning and evening surveys each day. The current analyses focus on data collected from the online baseline survey.

Recruitment and Participants

A convenience sampling strategy, focused on recruiting general populations of adults living in the U.S. during the COVID-19 pandemic, was utilized. To minimize in-person interactions, potential respondents were electronically invited through various social media platforms (e.g., Facebook, Twitter, Reddit, LinkedIn) and university-based email list servs of students, faculty, and staff. Inclusion criteria were as follows: 18 years or older, able to speak and read English, live in the U.S., and own and regularly use an Android or iPhone smartphone that they are willing to use to complete app-based surveys for the duration of the study. Exclusion criteria were as follows: enrolled in another study related to physical activity behaviors, including studies monitoring physical activity, intervening on physical activity, or examining the effects of wearable fitness trackers. Individuals were directed to an online screening form directly from an email or social media post. Once eligibility was determined, individuals agreed to participate through an online anonymous information sheet that described the study procedures, risks, and benefits. The Institutional Review Board of the University of

Southern California determined that the study procedures presented no more than minimal risk and approved it as exempt from full review (HS-20-00304).

Procedures

Participants completed the online screening form, information sheet, and baseline survey in English through an online survey platform. Baseline data collection took place over 45 days (April 10 – May 25, 2020), which cover the first 1-2 months after most U.S. states issued "Shelter-in-place" or "Stay-in-home" orders. The baseline survey took approximately 30 minutes to complete. Participants had the option to complete it either on their mobile phone, tablet, or desktop device. Upon completion of the baseline survey, participants were eligible to be entered into a lottery to win one of ten $50 gift cards.

Measures

In order to guide the development of the survey, recently published questionnaires on COVID-19 symptoms, diagnoses, and impacts were reviewed [14]. Authors included additional questions related to studying the impact of the COVID-19 pandemic on physical activity.

Self-reported physical activity. Participants completed the International Physical Activity Questionnaire Short Form (IPAQ-SF) [15] twice in the baseline survey. The IPAQ is one of the most widely used report-based physical activity instruments and has demonstrated acceptable reliability and validity across a range of populations [16 17]. The first time, the instructions asked individuals to "Think about the time you spent being physically active during a typical week in February 2020 (BEFORE THE COVID-19 PANDEMIC)," which represented the pre-COVID-19 period. The second time, the instructions asked individuals to "Think about the time you typically spent being physically active in the last 7 days PRIOR TO TODAY." Since the baseline survey was completed between April 10 – May 25, 2020, which covers the first 1-2

161 months after most U.S. states issued “Shelter-in-place” or “Stay-in-home” orders, this second
162 IPAQ administration represented the early-CVOID-19 period. During both times, participants
163 reported on levels of vigorous intensity activity, moderate intensity activity, and walking
164 activity. Vigorous intensity activities were described as “activities that take hard physical effort
165 and make you breathe much harder than normal” and included examples such as heavy lifting,
166 digging, aerobics, or fast bicycling. Moderate intensity activities were described as “activities
167 that take moderate physical effort and make you breathe somewhat harder than normal” such as
168 carrying light loads, bicycling at a regular pace, or doubles tennis. Walking activities were
169 described as including “walking at work and at home, walking to travel from place to place, and
170 any other walking that you have done solely for recreation, sport, exercise, or leisure.” For all
171 three types of physical activity, individuals reported the number of days per week that they
172 performed the targeted activity for at least 10 minutes at a time. They then reported how much
173 time they usually spent on one of those days doing the targeted physical activity. Data were
174 cleaned following the IPAQ scoring protocol [18]. Duration values were censored to a maximum
175 of 180 min per day to [19] reduce the effect of possibly spurious outliers.

176 *Device-based physical activity*. Stepping behavior was captured using the built-in
177 accelerometer from participants’ personal smartphones. Modern smartphones include a three-
178 axis gyroscope and accelerometer that capture body movements. iOS (Apple, Inc) and Android
179 (Google, Inc) operating systems come with default accelerometer applications that continuously
180 count steps taken by the user. Information about the underlying algorithm used by each
181 application to count steps was not available. Previous studies have demonstrated that
182 smartphones are valid tools for step counting in different age groups and across a range of
183 walking and running conditions [20]. These studies show that the phone’s position (e.g., carried

in a hip pocket by hand, or in a bag) does not greatly influence the accuracy of step counting. At the end of the online baseline survey, participants were asked to upload a screenshot of their past year steps-by-month from their Apple Health or Google Fit app. Detailed step by step instructions were provided on how the access this screen from the home screen of their personal devices. As Google Fit is not a predownloaded application, only 1 participant uploaded a screenshot from an Android device and 2 participants uploaded screenshot from the Fitbit application. The past year steps-by-month screen provides a visual bar graph display of the average steps per month recorded by the smartphone device over the past 12 months. To extract these data, screenshots were uploaded to WebPlotDigitizer [21] where the length of Y axis was measured and calibrated. The area of the bar graph was selected and the length of each bar from the graph was automatically extracted based on difference in color. Average steps by month was calculated rounded to the nearest whole number based on the length of the bar and were exported. Screenshots were excluded from extraction if an incorrect screenshot was uploaded (i.e. average miles by month) (n=21) or the quality of the screenshot was too poor to extract (n=6). The pre- and early-COVID-19 periods were represented by step count data extracted from Feb 2020 and April 2020, respectively.

Physical activity locations. Participants were asked whether they were currently physically active for at least 30 minutes per week. If so, they were asked to indicate where (i.e., the types of locations in which) they did physical activity over the past 7 days, with instructions to choose all that apply from the following options: inside my home or garage, in my yard or driveway, on the sidewalks and roads in my neighborhood, on the sidewalks and roads outside my neighborhood, gym or fitness center, at a park or trail, at an outdoor sports facility (e.g., basketball/tennis court, baseball diamond).

Demographics. Participants self-reported their biological sex at birth (male vs. female), age (later categorized as 18-39 years, 40-59 years, and 60+ years), ethnicity (Hispanic/Latino vs. non-Hispanic/Latino), and annual household income (later categorized as less than $27,000, $27,000-$59,999, $60,000-$99,999, $100,000 or more). Participants also reported their height (inches) and weight (pounds). Height was converted to meters, and weight was converted to kilograms. Body mass index (BMI; kg/m^2) was calculated, and weight status categories were created (underweight is < 18.5 kg/m^2, normal weight is ≥18.5 kg/m^2 and <25 kg/m^2, overweight is ≥25 kg/m^2 and < 30, obese is ≥30 kg/m^2).

Statistical Analyses

Prior to data analyses, variables were screened for violations of statistical assumptions (e.g., normality, linearity). All four physical activity variables (i.e., vigorous intensity, moderate intensity, walking, and step counts) were positively skewed and thus subjected to cube root transformations. A preliminary set of paired t-tests examined within-subject effects of time (pre-COVID-19 vs. early-COVID-19]) on vigorous intensity, moderate intensity, walking, and step counts. Mixed model repeated-measures analysis of variance (ANOVA) procedure examined the between-subject effects of self-reported ethnicity and annual household income on within-subject difference in physical activity the two time points (i.e., Time [WS] x Ethnicity [BS] and Time [WS] x Income [BS] after controlling for the main effects and interactions with time for age, sex, and weight status. To examine whether the likelihood of engaging in physical activity at the various locations also differed by self-reported ethnicity, logistic regressions were conducted with ethnicity and the covariates entered simultaneously and each location (yes vs. no) as the dependent variables in separate models controlling for the covariates listed above. Lastly, multiple linear regression analyses tested the associations of performing physical activity in

various locations (e.g., home/garage, driveway/yard, roads in one's neighborhood) (yes vs. no) with vigorous intensity, moderate intensity, walking, and step counts during the early-COVID-19 period after adjusting for the covariates listed above.

Statistical power analyses using G*Power [22] indicated that sample sizes of 250 (i.e., relevant to the full analytic sample) and 136 (i.e., relevant to the subsample with smartphone accelerometer data) are needed to detect small effect sizes (η^2= .011 - .015) and (η^2= .020 - .029), respectively, with $\beta = .80$, $\alpha = .05$, and correlation among measures of $r = .3$ in a repeated measures ANOVA testing a BS x WS interaction with two to four groups (BS) (i.e., Hispanic/Latino vs. non-Hispanic/Latino, annual household income categories) and two repeated measures (WS) (i.e., pre-COVID-19 vs. early-COVID-19). In multiple linear regression analyses, sample sizes of 248 (i.e., relevant to the full analytic dataset) and 140 (i.e., relevant to the subsample with smartphone accelerometer data) are needed to detect small effect size (f^2 = .032) and (f^2 = .057), respectively, with $\beta = .80$, $\alpha = .05$, and up to 11 predictor variables in the model.

Results

Data Availability and Demographic Characteristics

A total of 530 individuals expressed interest in the study and completed the screening questions. Of this number, n = 6 individuals were not eligible for living outside of the U.S., n = 3 were not eligible because they did not own a compatible Android or iPhone smartphone, n =9 were not eligible for being unwilling to comply with all of the study procedures, n = 13 were not eligible for currently participating in another research study examining physical activity behaviors. A total of 496 individuals were eligible after completing the screener, and 430 individuals consented for the study. Cases were removed that had not yet started (n = 19) or not

yet completed the baseline survey (n = 80) at the time of data analysis. Of the n = 331 remaining, 63 cases with missing data on one or more of the demographic covariates were removed, leaving an analytic sample size of 268. Table 1 shows the descriptive statistics for the demographic characteristics of the analytic sample. Approximately 58% of participants resided in California, but the sample included residents of 31 U.S. states and the District of Columbia. Participants ranged in age from 18-74 years old with an average age of 33.96 (SD = 12.2) years. A majority of participants were younger and female. Approximately 22% of the sample identified as Hispanic/Latino, which is somewhat higher than the rate in the general U.S. population (18.5%) according to recent census data [23]. There was a range of annual household incomes represented. Smartphone-recorded daily step counts were available for a subsample of n = 143 individuals. Chi-square tests showed that the subsample with available step count data was younger ($p < .001$) than the excluded sample without smartphone step count data.

Change in Physical Activity from the Pre- to Early-COVID-19 Periods

Descriptive statistics for vigorous, moderate, and walking physical activity per week as well as steps per day for the pre-COVID-19 (February 2020) and early-COVID-19 (April-May 2020) periods are shown in Table 2. Unadjusted paired t-tests indicated significant reductions in vigorous intensity, M_{diff} = -66.9 min/week (35.1% decrease), $t(267) = 6.30$, $p < .001$, moderate intensity, M_{diff} = -92.4 min/week (45.7% decrease), $t(263) = 6.30$, $p < .001$, walking, M_{diff} = -70.8 min/week (20.7% decrease), $t(264) = 4.62$, $p < .001$, and steps, M_{diff} = -2232.4 steps/day (36.3% decrease), $t(142) = 10.02$, $p < .001$ during the early-COVID 19 period as compared to the pre-COVID-19 period. Available past 12-month smartphone-based step count data show that average daily steps remained steady between May 2019 and February 2020, with marked decreased in daily steps in March and April 2020 (See Figure 1).

Results for the final mixed repeated measures ANOVA models examining changes in physical activity between the pre-COVID-19 and early-COVID-19 periods by self-reported ethnicity and annual household income are shown in Table 3. After controlling for the covariates in the model, changes in reported vigorous and moderate intensity physical activity did not differ by ethnicity or annual household income (See Table 3). However, there were significant Time (WS) x Ethnicity (BS) and Time (WS) x Income (BS) interactions for walking, indicating that the size of the change in minutes of walking physical activity per week differed by ethnicity (Hispanic/Latino vs. non-Hispanic/Latino) and annual household income. Figure 3 (Panel A) shows that Hispanic adults reported a greater decrease in walking physical activity minutes per week as compared to non-Hispanic adults. Also, adults with annual household incomes between $27,00- $59,999 reported a greater decrease in walking physical activity minutes per week as compared to adults with annual household incomes greater than or equal to $100,000 (see Figure 3, Panel B). The significant Time (WS) x Income (BS) interaction for step counts per day in Table 3 shows that after controlling for the effects of the covariates in the model, changes in recorded steps per day between the pre-COVID-19 and early-COVID-19 periods differed by annual household income. Adults with annual household incomes between $27,000- $59,999 showed a greater decrease in steps per day as compared to adults with annual household incomes greater than or equal to $100,000 (see Figure 3, Panel C).

Locations of Physical Activity During the Early-COVID-19 Period

A total of 236 participants indicated that they were currently physically active for at least 30 minutes per week, and thus provided physical activity location data. During the early-COVID-19 period, the greatest proportion of physical activity was reported at home or in one's garage (75.0%), followed by on the sidewalks or roads in one's neighborhood (69.9%), at a park

or trail (27.1%), on the sidewalks or roads outside one's neighborhood (19.9%), in one's yard or driveway (19.9%), gym or fitness center (5.1%), and outdoor sports facility (1.3%). Demographic differences in the likelihood of engaging in physical activity in the top three locations (i.e., home/garage, in neighborhood, park/trail) were examined. Individuals who had annual household incomes of $27,000-$59,999 (OR = 2.92, 95% CI = [1.13-7.63]), $60,000-$99,999 (OR = 2.79, 95% CI = [1.01,7.71]), or more than $100,000 (OR = 5.47, 95% CI = [2.11,-14.18]) than were more likely to engage in physical activity on sidewalks and roads in their neighborhoods than individuals whose annual household incomes were less than $27,000, after adjusting for age, sex, weight status, and ethnicity. Neither ethnicity nor annual household income were associated with the likelihood of engaging in physical activity at home/in garage or on at a park/trail.

Results of the multiple regression analyses predicting vigorous, moderate, walking, and step counts during the early-COVID-19 period as a function of the various locations that physical activity had been performed are shown in Table 4. Performing physical activity in one's home/garage or driveway/yard was associated with more vigorous and moderate intensity physical activity after adjusting for age, sex, weight status, ethnicity, and income. Also, a greater number of steps per day during the early-COVID-19 period was recorded for individuals who performed physical activity on the roads in their neighborhood and at parks/trails. None of the measured locations of physical activity were associated with walking physical activity.

Discussion

This study is one of the first known empirical investigations to examine the early effects of the COVID-19 pandemic on physical activity locations and behavior among adults living in the U.S. The baseline survey period represented the period of time (early-COVID-19, April –

May 2020) when states were under the most restrictive of the "Shelter-in-Place" and "Stay-at-home" orders, which prohibited most non-essential travel outside of the home. Results indicated that physical activity at all levels (vigorous, moderate, walking, and step counts) substantially decreased during this period as compared to the month (pre-COVID-19, February 2020) immediately leading up to the declaration of the COVID-19 national emergency in the U.S. However, declines in physical activity levels during the early-COVID-19 period were not universal across all sub-groups. Hispanic adults and those from lower income households experienced sharper decreases in self-reported walking min per week and recorded steps per day. These inequities begin to indicate how certain population sub-groups may be hit harder by the COVID-19 pandemic in terms of its impact on health-related behaviors. Given the potential for increased risk of obesity, diabetes, and other chronic diseases due to prolonged physical inactivity; immediate communication, programmatic, and policy efforts should be directed towards addressing barriers and promoting physical activity in these high risk groups during the next few months of the pandemic.

Overall, physical activity levels declined dramatically during the early-COVID-19 period. Observed changes for self-reported physical activity ranged from a 21% decrease for walking to an almost 46% decrease for moderate intensity. These values are similar in size to percent changes in the range of 32% – 48% found for overall physical activity on recent self-report surveys of U.S. adults for the late March to early April period [10 11]. Previous data from wearable activity tracking devices collected during the same time frame have found smaller decreases in physical activity levels ranging from 7% – 12% [24 25], whereas step counts from personal smartphone accelerometers decreased by about 36% in the current study. However, accelerometer data from the two earlier studies was collected through wrist-worn devices, which

345 may capture more light intensity physical activity in the home than personal smartphones that
346 may be left in stationary locations (e.g., table, kitchen counter) when at home. In the current
347 study, the largest reductions were observed for self-reported moderate and vigorous intensity
348 physical activity, which is may be due to the closure of gyms/fitness facilities that provide
349 cardiovascular and weight-lifting equipment, as well as group exercise classes, such as HIIT
350 (high-intensity interval training) and spin classes. Data from the current study showed that only
351 5% of participants reported performing physical activity in a gym or fitness center in the past 7
352 days during the early-COVID-19 period. The positive association between performing physical
353 activity at a home location and higher levels of moderate/vigorous activity suggests that
354 individuals may attempt to replace these gym and fitness center resources with online/streaming
355 fitness classes or available equipment at home. The smallest decreases were observed for
356 minutes of self-reported walking per week. This finding, coupled with results showing that step
357 counts are positively associated with walking in one's neighborhood and parks, suggests that
358 neighborhood- or park-based walking may be a viable option for maintaining physical activity
359 over the course of an extended pandemic.

360 Results suggest that decreases in self-reported walking and device-based step counts were
361 larger for individuals from lower-income households. Additionally, adults identifying as
362 Hispanic/Latino demonstrated larger decreases in walking during this period. A possible
363 explanation for patterns of greater decline for these vulnerable groups is COVID-19-based
364 elimination of transport- and occupational-based walking among individuals who previously
365 traveled to work all or part of the time by walking or public transportation, or who previously
366 engaged in walking while at work due to the nature of their job position. Location data during the
367 early-COVID-19 period indicate that individuals from lower income households were less likely

to report engaging in physical activity on the sidewalks and roads in their neighborhood. Several reasons may account for this finding, such as the possibility that transport- or occupational-based physical activity is not being replaced by leisure walking in the neighborhood. Also, it is possible that streets in lower income neighborhoods have poorer sidewalk availability and quality, greater traffic volume, or higher crime, which can deter leisure walking [26]. Additional reasons for larger declines in step counts for individuals from lower income households may include being less likely to be able to afford home exercise equipment or access to online streaming exercises classes and being more negatively impacted by changes in employment or increased childcare requirements. These patterns indicate potential health concerns for these high risk groups unless affordable and easily accessible opportunities for home- or neighborhood-based physical activity become available and structural inequities are addressed. Findings observed here suggest that disparate impacts of the COVID-19 pandemic on lower income and ethnic minority groups reach beyond viral exposures and mortality [27], and extend into health-related behaviors that may have long-lasting consequences for other chronic diseases.

Strengths of the study included the timeliness of the baseline survey during the early-COVID-19 period (April – May 2020), the collection of retrospective data to capture the period prior to the pandemic, and the use of standardized self-report and objective physical activity measures. However, there were some limitations. The use of a retrospective self-report measures to assess pre-COVID-19 levels of vigorous, moderate, and walking physical activity could have introduced various reporting errors and biases. However, the within-subject design limits these concerns by only comparing each participant to themselves. Furthermore, observed declines in self-reported physical activity were replicated using objective smartphone-based accelerometer data. Although individuals may not carry their smartphones with them at all times, this method is

391 growing in applicability as way to capture gross time-activity patterns in a variety of
392 epidemiological and population-based research studies [28]. An additional limitation of the
393 study was the substantial number of participants who had started by had not yet completed the
394 full baseline survey by the time of data analysis. Participants were able to postpone the
395 completion of the baseline survey to a time that was more convenient for them. However, the
396 length of the online survey (about 30 min) may have introduced some burden, which reduced
397 completion rates Lastly, the sample largely consisted of younger adults who were female.
398 Findings may not extend as well to older adults or males.

399 *Conclusions*

400 In summary, results from this study found that physical activity among adults decreased
401 dramatically during the first two months of the "Shelter-in-Place" and "Stay-at-home" order
402 issued by states during the COVID-19 pandemic. Although these restrictions were necessary in
403 order to slow the spread of the virus and allow healthcare facilities to build capacity, there may
404 be unintended consequences on other health-related behaviors such as physical activity.
405 Disparate impacts of the COVID-19 pandemic on the physical activity levels of potentially
406 vulnerable sub-groups, including individuals who are low income or Hispanic/Latino, underscore
407 the need for population-specific physical activity programs and policies over the next several
408 months to years as the pandemic continues.

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Tables

Table 1: Descriptive Statistics for Sample on Demographic Characteristics

Variable	*n (%)*
Age Group	
18-39 years	207 (77.2)
40-59 years	46 (17.2)
≥60 years	15 (5.6)
Sex	
Male	52 (19.5)
Female	215 (80.5)
Ethnicity	
Hispanic/Latino	58 (21.6)
Non-Hispanic/Latino	210 (78.4)
Annual Household Income	
Less than $27,000	36 (13.4)
$27,000 - $59,999	70 (26.1)
$60,000 - $99,999	48 (17.9)
$100,000 or more	114 (42.5)
Weight Categories	
Underweight	7 (2.6)
Normal weight	143 (53.4)
Overweight	79 (29.5)
Obese	39 (14.6)

N = 268.

Table 2: Descriptive Statistics for Self-reported and Device-based Physical Activity Variables

	Pre-COVID-19 (Feb. 2020)			Early-COVID-19 (April-May 2020)		
	n	**Mean (SD)**	**Median**	***n***	**Mean (SD)**	**Median**
Vigorous (min/week)	268	190.7 (211.2)	120.0	268	123.9 (171.4)	60.0
Moderate (min/week)	265	202.4 (271.9)	120.0	266	111.0 (172.5)	60.0
Walking (min/week)	266	341.9 (339.8)	210.0	267	244.1 (280.8)	140.0
Steps (counts/day)	149	6153.2 (2805.9)	5998.0	143	3920.8 (3344.5)	3058.0

Self-reported minutes of vigorous, moderate, and walking physical activity per week were assessed by the short-form International Physical Activity Questionnaire (IPAQ). Device-based step counts per day were assessed by the on-board accelerometer in participants' personal smartphones. Median values are presented due to positive skew.

Table 3: Mixed Model Repeated-Measures Analysis of Variance (ANOVA) Examining the Effects of Time (pre-COVID-19 [Feb. 2020] vs. early-COVID-19 [April-May 2020]) on Self-reported and Device-based Physical Activity by Ethnicity and Income

	Vigorous (min/week)				Moderate (min/week)				Walking (min/week)				Steps (counts/day)			
Variable	***df***	***F***	***p***	**η^2**	***df***	***F***	***p***	**η^2**	***df***	***F***	***p***	**η^2**	***df***	***F***	***p***	**η^2**
Time (WS)	1,259	10.602	.001	.040	1,255	16.686	.000	.062	1,266	9.247	.003	.035	1,132	5.716	.018	.042
Hispanic (BS)	1,259	1.410	.236	.005	1,255	.109	.742	.000	1,266	3.655	.057	.014	1,132	1.291	.258	.010
Income (BS)	3,259	2.335	.074	.027	3,255	.631	.596	.007	3,266	0.844	.471	.010	3,132	3.017	.032	.064
Time (WS) x Hispanic (BS)	1,259	1.071	.302	.004	1,255	.694	.405	.003	1,266	4.289	.039	.017	1,132	0.129	.720	.001
Time (WS) x Income (BS)	3,259	0.617	.604	.007	3,255	1.203	.309	.014	3,266	2.935	.034	.034	3,132	3.075	.030	.065

n = 268 for vigorous, n = 264 for moderate, n = 265 for walking, and n =143 for steps. η^2 = effect size (partial eta squared). WS = within-subject effect. BS = between-subject effect. Self-reported minutes of vigorous, moderate, and walking physical activity per week were assessed by the short-form International Physical Activity Questionnaire (IPAQ). Device-based step counts per day were assessed by the on-board accelerometer in participants' personal smartphones. Vigorous, moderate, walking, and steps were cube root transformed to adjust for positive skew. Hispanic/Latino (vs. non-Hispanic/Latino), and annual household income ($12,500-$26,999, $27,000-$59,999, $60,000-$99,999, more than $100,000). All models adjust for the main effects and interactions of age (18-39 years, 40-59 years, and 60+ years), sex (male vs/ female), and weight status (underweight is < 18.5 kg/m^2, normal weight is ≥18.5 kg/m^2 and <25 kg/m^2, overweight is ≥25 kg/m^2 and < 30, obese is ≥30 kg/m^2) with Time.

Table 4: Multiple Linear Regression Analysis for Self-reported and Device-based Physical Activity During the early-COVID-19 (April-May 2020) Period as a Function of Past 7-day Physical Activity Locations

	Vigorous (min/week)				Moderate (min/week)				Walking (min/week)				Steps (counts/day)			
Physical Activity Location	***β***	***SE***	***p***	**ΔR^2**	***β***	***SE***	***p***	**ΔR^2**	***β***	***SE***	***p***	**ΔR^2**	***β***	***SE***	***p***	**ΔR^2**
Home/Garage	1.579	.436	<.001	.056	1.333	.410	.001	.040	0.079	.382	.836	<.001	-0.374	.934	.689	.011
Driveway/Yard	1.136	.464	.015	.025	1.201	.440	.007	.029	0.124	.410	.763	<.001	1.142	.924	.219	.006
Roads in Neighborhood	-0.203	.409	.619	<.001	0.102	.387	.793	.001	0.508	.361	.161	.010	2.081	.804	.011	.062
Roads outside Neighborhood	0.875	.467	.063	.017	0.296	.445	.507	.030	0.472	.410	.250	.008	1.207	.947	.205	.028
Gym/Fitness Center	-0.004	.847	.996	<.001	1.081	.797	.177	.008	-0.405	.743	.587	.001	1.955	1.755	.268	.010
Park/Trail	0.315	.420	.454	.002	0.301	.396	.448	.002	0.336	.369	.363	.003	1.781	.846	.038	.029

n = 235 for vigorous, n = 233 for moderate, n = 234 for walking, and n =124 for steps. SE = standard error. ΔR^2 = change in r-squared value. Self-reported minutes of vigorous, moderate, and walking physical activity per week were assessed by the short-form International Physical Activity Questionnaire (IPAQ). Device-based step counts per day were assessed by the on-board accelerometer in participants' personal smartphones. Vigorous, moderate, walking, and steps were cube root transformed to adjust for positive skew. Physical activity locations (i.e., where physical activity occurred in past 7 days) coded 1= yes and 0 = no. Participants who reported less 30 min physical activity per week did not receive past 7-day physical activity questions (n = 32). All models adjust for age (18-39 years, 40-59 years, and 60+ years), sex (male vs. female), weight status (underweight is < 18.5 kg/m^2, normal weight is ≥18.5 kg/m^2 and <25 kg/m^2, overweight is ≥25 kg/m^2 and < 30, obese is ≥30 kg/m^2), ethnicity (Hispanic/Latino vs. non-Hispanic/Latino), and annual household income ($12,500-$26,999, $27,000-$59,999, $60,000-$99,999, more than $100,000).

459 Figure Captions

460 *Figure 1.*

461 Average steps (counts/day) for the past 12 months (May 2019-April 2020) for study participants.

462 Step data extracted from personal smartphone accelerometer tracking app on iOS and Android.

463

464 *Figure 2.*

465 Panel A: Effects of time (pre-COVID-19 [Feb. 2020] vs. early-COVID-19 [April -May 2020])

466 on minutes of walking physical activity per week by ethnicity (Hispanic/Latino n = 57, non-

467 Hispanic/Latino n = 208). Estimated marginal means are presented for raw (untransformed) data

468 adjusting for sex, age, weight status, and annual household income. n = 265.

469

470 Panel B: Effects of time (pre-COVID-19 [Feb. 2020] vs. early-COVID-19 [April -May 2020]) on

471 minutes of walking per week by annual household income (n = 36 for <$27,000, n = 70 for

472 $27,000-$59,999, n = 48 for $60,000-$99,999, n = 111 for ≥ $100,000). Estimated marginal

473 means are presented for raw (untransformed) data adjusting for sex, age, weight status, ethnicity.

474 n = 265.

475

476 Panel C: Effects of time (pre-COVID-19 [Feb. 2020] vs. early-COVID-19 [April 2020]) on

477 smartphone accelerometer-derived steps per day by annual household income (n = 23 for

478 <$27,000, n = 38 for $27,000-$59,999, n = 23 for $60,000-$99,999, n = 59 for ≥ $100,000).

479 Estimated marginal means are presented for raw (untransformed) data adjusting for sex, age,

480 weight status, and ethnicity. n = 143.

481

Figures

Figure 1

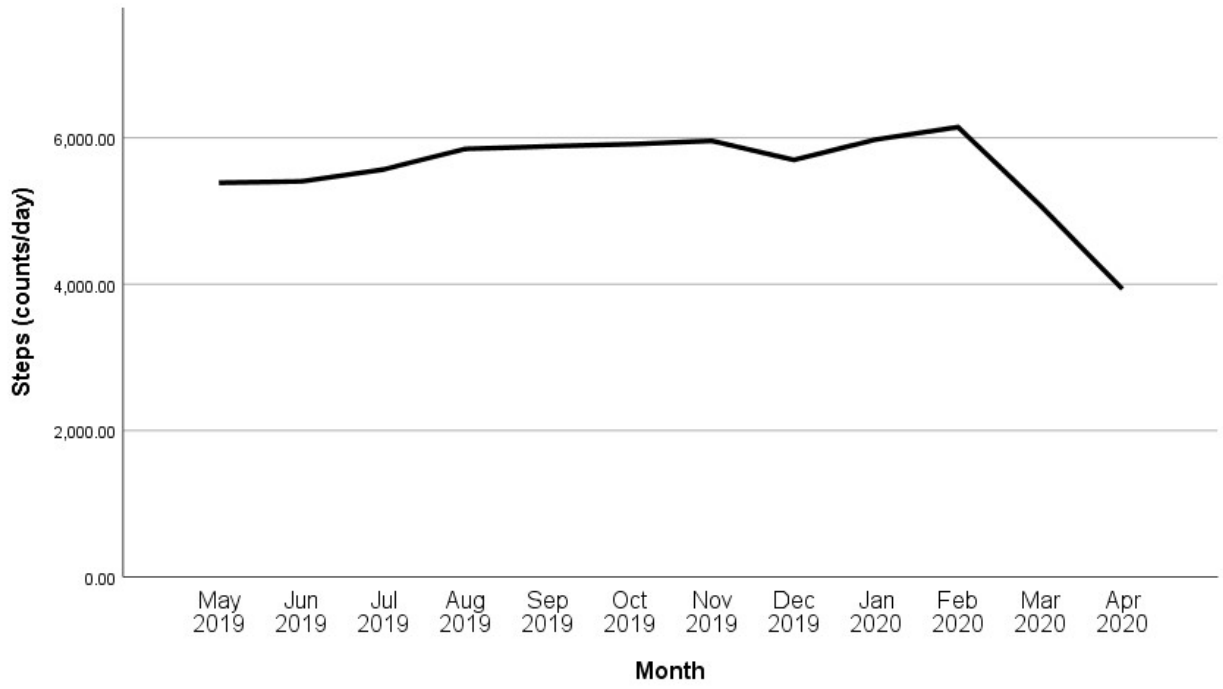
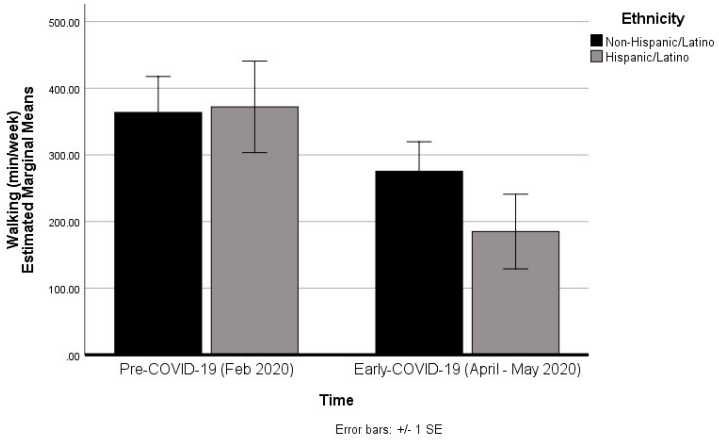


Figure 2

Panel A



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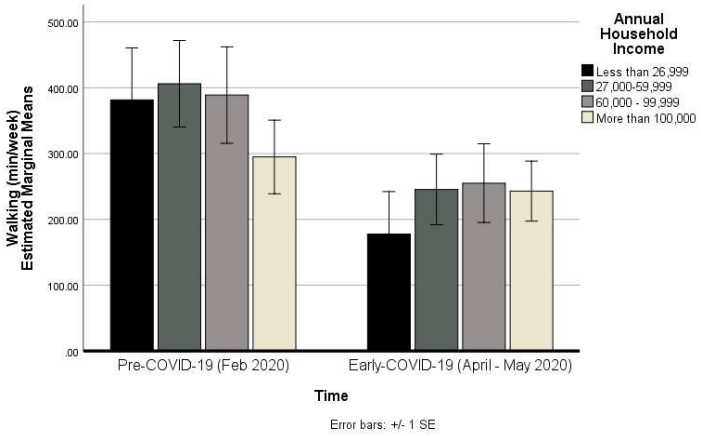
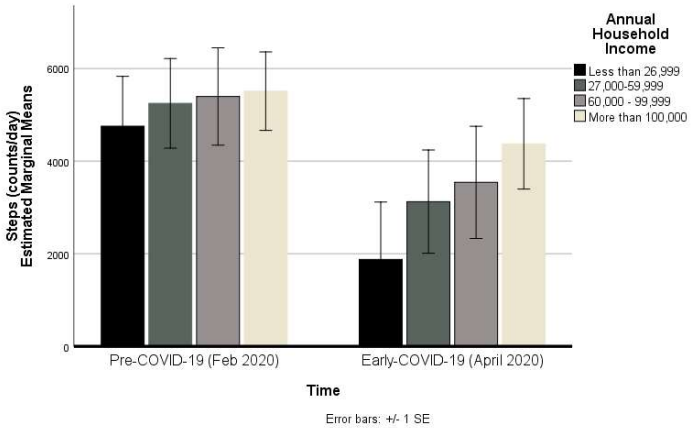


Panel C



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