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The disparate impact of COVID-19 pandemic on walking and biking behaviors

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\textbf{A B S T R A C T}

This study sought to assess changes in active transportation behaviors due to the COVID-19 pandemic, in addition to identifying the disparate impacts between sociodemographic groups. A survey was conducted in November 2020, which collected responses from 1,000 Michigan residents statewide regarding walking and biking behaviors before, during, and anticipated post-pandemic. The survey found that people who walked or biked frequently for recreation before the pandemic maintained or increased their activities during the pandemic. More importantly, the survey also revealed differing pandemic-related impacts on walking and biking behaviors between sociodemographic groups. Specifically, people from underprivileged sociodemographic groups, such as those who are older, have lower education or income level, or identify as a minority, were less active in general before the pandemic, and these walking and biking behavior gaps were exacerbated by the pandemic. Furthermore, the elevated negative impacts on these sociodemographic groups were anticipated to continue in the future.

1. Introduction

Since March 2020, the COVID-19 pandemic has disrupted everyday mobility across the United States. As a response to the pandemic, people modified their daily activity habits and commuting routines. Telecommuting, or working from home, has become routine for many around the world (Salon et al., 2021). Some people have purchased cars to avoid riding public transit, while others have begun utilizing micromobility, such as shared bikes and E-scooters (Bert et al., 2020). In response to the shutting down of fitness centers and the reduction of overall trips, many Americans turned to walking and biking for recreational activity and physical fitness (Cusack, 2021). These mobility changes, compounded by existing socioeconomic disparities, may have impacted walking and biking behaviors in ways that are not yet fully understood.

There have been mixed responses to the pandemic in terms of walking and biking behaviors. The pandemic has deterred many from going out to crowded areas due to a high risk of infection, especially among those who are older or having underlying health conditions (Ozbilen et al., 2021; Barbieri, et al., 2021). However, socially distanced opportunities for recreation became readily apparent and many cities, such as New York City and Chicago, converted some of their streets for pedestrian and bicycle use to support the increase in demand for socially distanced walking and biking space (Fischer and Winters, 2021; Kraus and Koch, 2021).

Many works of literature have been published focusing on micromobility use (Jobe and Griffin, 2021; Menon et al., 2020; Wang and
The most agreed upon deterrent to bicycling was the distance from origin to destination (Fang, 2020). Of pedestrian trips, up to 64% have been found to start from home (Watson et al., 2021). In a study performed in the San Francisco Bay Area, the most agreed upon deterrent to bicycling was the distance from origin to destination. This study aimed to fill these current research gaps by examining the impacts of the COVID-19 pandemic on the walking and bicycling behavior between different sociodemographic groups. Specifically, this study investigated the self-reported walking and bicycling behaviors across three time periods: before, during, and anticipated post-pandemic. The research hypothesis is that the impacts of the pandemic on active transportation may vary based on sociodemographic status. Three research questions were addressed:

1. How was walking and biking behavior impacted by the COVID-19 pandemic?
2. How did sociodemographic status impact the change in walking and biking behaviors as a result of the pandemic?
3. How did sociodemographic status impact the anticipated walking and bicycling behavior post-pandemic?

It is widely known that physical exercise can help build human immune systems to fight diseases (Cusack, 2021) and that walking and bicycling provides a source of exercise for many. As the world moves beyond the pandemic, it is important to understand the pandemic’s impact on walking and bicycling behaviors and subsequent impacts on personal health. Such knowledge can help public health officials implement policies aimed at alleviating the impact of the pandemic on populations adversely affected by it. Furthermore, such knowledge will aid transportation officials in decision making when investing in active modes to support potential changes in travel behavior.

2. Literature review

Three aspects of literature regarding the COVID-19 pandemic’s impact on walking and bicycling behaviors were reviewed. These include a review of general factors that influence walking and bicycling behavior, the impact of the pandemic on active transportation, and equity considerations regarding the impact of COVID-19 on travel behaviors.

2.1. Factors influencing walking and biking

Many studies investigated the status of bicycling and walking prior to the pandemic. The structure of the built environment and land use greatly impacts the prevalence of active transportation (Ewing and Cervero, 2010; Cao et al., 2009; Boarnet and Crane, 2001). These elements include urban compactness, mixed-use development, pedestrian friendly streets, intersection density and transit frequency (Mahmoudi and Zhang, 2021), and proximity to education and public administration land uses (Yang and McAndrews, 2020). Access to protected bicycle infrastructure (Dai and Dadashova, 2021) and proximity to separate paths or trails (Porter et al., 2020) were also associated with increased bicycling trips.

Due to the aforementioned factors, Dong (2020) found that bicycling was much more prevalent in urban areas than suburban areas. Of pedestrian trips, up to 64% have been found to start from home (Watson et al., 2021). In a study performed in the San Francisco Bay Area, the most agreed upon deterrent to bicycling was the distance from origin to destination (Fang, 2020).

Several sociodemographic factors have also been linked to active transportation use. Studies have been conducted to identify relevant factors between socioeconomic status and walking by trip purpose. Pucher et al. (Pucher et al., 2011) found that people with less than a high school diploma did not demonstrate increased rates of walking five times per week from 2001 to 2009 using National Household Travel Survey data (NHTS). Mondschein (Mondschein, 2021) also used NHTS data to examine the distribution of walking across socioeconomic status from 2001 to 2017. This study revealed less walking by adults with middle socioeconomic status and more walking by adults with high socioeconomic status in urban areas. Cao et al. (2009) and Handy et al. (2006) found that income was positively correlated with walking for leisure, but not with walking to stores. Agrawal & Schimek (2007) associated utilitarian walking with educational attainment and recreational walking with higher income. Several studies found that immigrants, the poor, and the young were more likely to walk (Clifton, 2003; Blumenberg, 2009).

Infrastructure and safety were factors associated with bicycling barriers. People of color and those of lower socioeconomic status were less likely to cycle and more likely to face infrastructure and other safety related barriers when cycling (Braun, 2021). African and Latino Americans were ticketed while bicycling eight times and three times more frequently, respectively, compared to White Americans (Barajas, 2021). Women were also more likely than men to report that bicycling to work makes someone too sweaty for work and that the clothes necessary for bicycling were not compatible with work clothes (Fang, 2020).

Another concentration of literature focuses on the relationship of active transportation with health benefits, with the implication that active transportation engagement is positively associated with perceived health benefits. People of color and those with lower socioeconomic status were less likely to associate bicycling with health benefits (Barajas and Braun, 2021; Braun, 2021). Women were also found to be less likely to associate walking trips with health benefits (Barajas and Braun, 2021). Additionally, the health benefits of walking were more greatly perceived by those that engaged in home-based walking trips versus non-home-based trips (Pae and Akar, 2020).
2.2. Active transportation during the pandemic

A plethora of scientific papers and news articles have been published detailing national and international trends toward the increase in active transportation, especially bicycling, during the COVID-19 pandemic. Data from Streetlight reported an average increase of 12 % in bike trips made in the United States between July 2019 and July 2020 (Buehler and Pucher, 2021). Many survey respondents indicated that they were cycling more during the pandemic (Bert et al., 2020; Ehsani et al., 2021; Lock, 2020). Governments across the world responded by introducing interventions for cyclists such as pop-up infrastructure, free bike share, and e-bike subsidies (Menon et al., 2020; Nikitas et al., 2021; Fischer and Winters, 2021; Bucsky, 2020; Kraus and Koch, 2021). Bike sales increased substantially across the world (Lock, 2020; Lozzi et al., 2020; Luan et al., 2021; Molloy et al., 2021) and the United States (Goldbaum, 2020; Spelbring et al., 2020), with some bike shops in New York City reporting a threefold growth in bicycle sales (Kaufman et al., 2020). In Chicago, bikeshare, compared to other modes, was the fastest to rebound by the end of July 2021, increasing 284 % from the baseline compared to 138 % for driving, 132 % for walking, and 83 % for all other modes (Hu et al., 2021).

The shift in modal share away from transit to active transportation was identified in cities with high shares of commuters using public transit prior to the pandemic, especially in European cities (Lozzi et al., 2020; Molloy et al., 2021; Scorrano and Daniels, 2021; Zhang and Fricker, 2021; Möllers et al., 2021) and large American cities such as New York, Boston, and Chicago (Wang and Noland, 2021b; Padmanabhan et al., 2021; Hu et al., 2021; Teixeira and Lopes, 2020; Kaufman et al., 2020). In Germany, ten cities that were studied found that bicycling decreased in bike-oriented university towns while cities that were more transit oriented experienced increases in bicycling (Zhang et al., 2021). Additionally, several studies report evidence that average bikeshare trip length increased to over 30 min in several American cities at the peak of the pandemic in March and April 2020, suggesting essential workers were replacing longer transit trips with bikeshare for commuting purposes (Wang and Noland, 2021b; Padmanabhan et al., 2021; Teixeira and Lopes, 2020). Data from bikeshare services and major trails demonstrated the increased adoption of bicycling for recreational purposes. The number of trips that started and finished at the same station, also referred to as a “round-trips,” increased from 4.58 % in 2019 to 12.69 % in 2020 in Chicago (Hu et al., 2021). As well, the number of “casual” users, who are more likely to bicycle for recreational purposes, increased relative to “subscribed” users (Padmanabhan et al., 2021; Hu et al., 2021). Rails-to-Trails reports a 51 % increase in use from 2019 to 2020 using data collected from 31 trail counters distributed across the country (Rails-to-Trails Conservancy, n.d.) and the East Coast Greenway reported increases ranging from 65 % to 300 % in some trail segments (East Coast Greenway Alliance, n.d.). In Chicago reporting indicated the pattern of trips changed from a two-peak “commuting pattern” to a “one-peak” leisure pattern from 2019 to 2020, as well as weekends becoming more popular than weekdays (Hu et al., 2021).

The increase of bicycling, however, varied from region to region across the United States. Ehsani et al. (2021) found that the Midwest bicycled less frequently than other regions of the United States. Additionally, Zhang and Fricker (Zhang and Fricker, 2021) found that non-motorized activity decreased in very dense urban areas, like New York City, Boston, and San Francisco, but increased in less dense urban areas, such as Charlotte, NC, Tallahassee, FL, and Indianapolis, IN.

It was anticipated by surveys that active transportation users in large urban areas will continue to bicycle and walk more post-pandemic. One survey of large urban areas in the US reported that 25 % of users indicated they intended to make more trips using their personal bike, e-scooter, or walking after the pandemic compared to before the pandemic, though shared bikes and e-scooters were less likely to be used (Bert et al., 2020). Another survey found that respondents across the US anticipated to bicycle more after the pandemic compared to before, and that this anticipation was greater than other modes of transportation, including transit, walking, and using personal vehicles (Ehsani et al., 2021). Although with similar anticipations of more walking and biking, Salon et al. found that 30 % of Americans nationwide intended to take more walks post-pandemic and 15 % of Americans intend to bike more (Salon et al., 2021). Bert et al. also reported that frequent walkers and users of personal bikes and e-scooters were the most likely to anticipate maintaining that mode of transportation post-pandemic (Bert et al., 2020).

2.3. Equity impact of COVID-19 on travel behaviors

Few studies have examined the COVID-19 pandemic’s impact on travel behaviors across sociodemographic groups, particularly active transportation behaviors. Studies revealed that people of color, people living in lower income areas, or people with lower educational attainment did not have other travel options but either were more likely to remain on transit or reduce travel due to lack of transportation options during the pandemic. Hu and Chen (2021) studied transit ridership data in Chicago and found greater declines in transit ridership during the pandemic in areas with more commercial land use and higher percentages of white, educated, and high-income individuals, while regions with greater COVID-19 cases/deaths had smaller declines in transit ridership. Ma et al. (2022) conducted a survey in Australia and found that Asians were less likely to increase walking than White people due to higher levels of discrimination. Abdullah et al. (2020) found that gender, car ownership, employment status, travel distance, primary travel purpose, and underlying pandemic-related factors significantly impacted mode choice during the pandemic. One study (Darr and Zhang, 2021) used daily bikeshare ridership in San Francisco to determine if ridership was significantly affected by demographics and COVID-19 related temporal data. The results showed that a low-income area was negatively correlated with the number of trips before and during the pandemic.

3. Background on commuter travel and COVID-19 STAY-AT-Home orders in Michigan

According to American Community Survey (American Community Survey, 2019), Michigan residents travel to work by car at a
higher rate (90.7 %) compared to the rest of the United States (84.8 %). More than half of this difference is accounted for by the lower public transit ridership in Michigan (1.4 %) compared to the United States (5.0 %). Reinforced by findings from literature previously discussed, the suburbanization of Michigan’s population is likely a factor driving the prevalence of auto use for daily travel. This is very pronounced in the Metro Detroit area where the City of Detroit’s population has fallen to roughly a third of its 1950 peak population of 1.8 million while the metro population has grown and stabilized during that time. Michigan also has lower walking (2.2 %) and biking (0.3 %) mode shares than the United States averages of 2.6 % and 0.5 %, respectively.

In March 2020, Michigan governor issued a Stay-at-Home order to slow down the spreading of the virus (Witsil, 2021). By the beginning of June, the first wave of the virus was nearing its end and the state began to loosen restrictions on the stay-at-home order, allowing for more restaurants and businesses to reopen at limited capacity (Witsil, 2021). Over the summer months cases remained low compared to the early months of the pandemic. Cases began surging again in October 2020 and Michigan’s second wave of the virus peaked the following month (Witsil, 2021). This was followed by a second Stay-at-Home in November 2020. At that time, vaccinations were not available to the public (Witsil, 2021).

At the beginning of the pandemic, essential workers still needed to commute to work. Many of these workers were in the service sector, more likely to be of lower socioeconomic status, and dependent on transit (TRB Executive Committee et al., 2021). While transit commute trips transitioned to bicycle trips in many American cities, the literature suggests this was less likely to occur in Michigan due to a variety of factors. First, sprawling land use within Michigan’s urban areas, especially Detroit, reduces the feasibility of active transportation trips due to greater travel distances. Also, Michigan has few bikeshare services, only covering small areas in Detroit and Grand Rapids. The combination of these factors suggests that the pandemic related mobility changes experienced by many large metro areas across the United States would likely not be reflected in Michigan.

4. Methodology

This study used the State of the State Survey (SOSS) to study people’s walking and biking behaviors in the State of Michigan. The Michigan State University (MSU) Institute for Public Policy and Social Research (IPPSR) has administered the SOSS regularly since 1994 (IPPSR., n.d.). Two of the main goals of the SOSS are to capture Michigan citizens’ opinions on timely issues and collect data for scientific and policy research. Every SOSS is unique in its questionnaire which is formed by combining survey questions from researchers in various fields. The SOSS currently uses online methods to survey participants who are from a stratified random sample of Michiganders representing the general population in Michigan. The SOSS survey methodology and data is available to the public (Pierce, 2020).

4.1. Data collection

The 80th round of the SOSS was conducted in November 2020 when Michigan was in the peak of the second wave of COVID-19. The SOSS sought to collect walking and biking behaviors from 1,000 Michigan adults through an online survey administered by YouGov under contract with the MSU IPPSR. The nine categories of sociodemographic information collected from the survey included:

1. Age
2. Gender
3. Ethnicity and Race
4. Marital status
5. Children in house
6. Employment status
7. Household Income level
8. Education
9. Place of Residence

A series of questions about personal walking and biking behaviors was asked in the survey. Four of the questions related to the research hypothesis were used:

1. How often do you travel on foot within your community for each of the following activities?
2. How often do you travel by bicycle within your community for each of the following activities?
3. Compared to the same period last year, how often have you gone walking or bicycling during the COVID-19 pandemic?
4. In the future, do you intend to continue at your current frequency or change it?

For the Questions 1 and 2, walking and biking activities were classified into 3 purposes: 1) Recreation or exercising, 2) Going to a store, restaurant, or another business, and 3) Commuting to work or school. The frequencies of these activities were measured in a 7-level scale: 1) Daily, 2) More than once a week, 3) Once a week, 4) More than once a month, 5) Once a month, 6) A few times a year, and 7) Never.

For Questions 3 and 4, walking and biking were measured separately. For Question 3, the answers were coded in a 5-level scale and an “Unsure” category: 1) Much less frequently, 2) Somewhat less frequently, 3) About the same, 4) Somewhat more frequently, 5) Much more frequently, and 6) Unsure. For Question 4, the responses were measured in a 3-level scale and an “Unsure” category: 1)
Plan to Decrease, 2) Don’t Plan to Change, 3) Plan to Increase, and 4) Unsure.

4.2. Data analysis

Both descriptive analysis and tests of statistical significance were performed to answer the research questions.

4.2.1. Data aggregation

The following data aggregation was performed to facilitate the statistical analysis.

1) For survey questions 1 and 2, the original 7-level scale response data were aggregated into a new 3-level scale as shown in Fig. 1.
2) For survey question 3, the original 5-level scale was aggregated into a 3-level scale as shown in Fig. 1.
3) For survey question 4, no data aggregation was performed.

4.2.2. Statistical methods

Two relationships were analyzed for three time periods: pre-pandemic, during the pandemic, and post-pandemic (anticipated). These two relationships are:

1. Sociodemographic factors in relation to respondents’ walking and biking behaviors.
2. The consistency in walking and biking behaviors over the three time periods.

A multinomial logistic regression (MNL) model was used to analyze these relationships, as the data are categorical in nature. A linear predictor function was set up to examine how walking and biking behaviors vary with respect to various sociodemographic characteristics (e.g., age, gender, race, etc.) and behaviors in previous time periods. This function is of the following form:

\[ U_{ij} = \alpha_j + X_i \beta_j \]  

where \( \alpha_j \) is a constant term that is specific to walking or biking behavior category \( j \) (e.g., frequently, occasionally, almost never, etc.), \( X_i \) is a vector of independent variables (e.g., age, gender, race, etc.) that are related to walking or biking behavior scenario \( i \) (e.g., pre-pandemic walking behavior for recreation purpose, pre-pandemic biking behavior for commute purpose, etc.), \( \beta_j \) is a vector of estimable parameters. Therefore, the probability of someone exhibiting walking or biking behavior choice \( j \) is given by the following expression:

\[ P_{ij} = \frac{\exp(\alpha_j + X_i \beta_j)}{\sum_{j=1}^J \exp(\alpha_j + X_i \beta_j)} \]  

As found in the literature, people exhibit different walking and biking behaviors for different trip purposes. Therefore, walking and biking behaviors were modeled separately for different trip purposes. For survey questions 1 and 2, which correspond to pre-pandemic walking and biking behaviors respectively, one MNL model for each of the three trip purposes (i.e., recreation, commute, and service).

| Daily | Frequently | Much less frequently | Decreased |
|------|-----------|----------------------|----------|
| More than once a week | Occasionally (Reference category) | Somewhat less frequently | About the same frequently |
| Once a week | Almost Never | About the same | About the same (Reference category) |
| More than once a month | | Somewhat more frequently | Increased |
| Once a month | | Much more frequently | |
| A few times a year | | Unsure | |
| Never | | Unsure | |

Survey Questions 1 and 2

Survey Question 3

Fig. 1. Survey Questions Data Aggregation.
was used to examine the behavior. In the models for walking or biking behaviors during and post pandemic (i.e., survey questions 3 and 4), the respective behavior in the prior period was included as an independent variable to study the behavior changes over time.

For pre-pandemic, during-pandemic, and post-pandemic models, the “Occasionally,” “About the same,” “Do not plan to change” behavior was set as the reference category, respectively. For identification purposes, the coefficients for the reference were normalized to zero. Therefore, results for walking and biking behaviors can be interpreted in relation to the reference.

5. Results and discussion

A total of 1000 survey responses were obtained. Table 1 shows the summary of survey participants’ sociodemographic distributions. 51% of the survey respondents were female and 22% of respondents were over 65 years old. Half of respondents were not active in labor force at the time of the survey; one-third with less than $30,000 annual household income and over two-thirds had less than a 4-year college education.

Table 1
Sociodemographic Statistics for Survey Participants.

| Variable                      | Count* | Percentage (%) |
|-------------------------------|--------|----------------|
| Gender                        |        |                |
| Male                          | 486    | 48.6           |
| Female*                       | 508    | 50.8           |
| Intersex/Other                | 6      | 0.6            |
| Age                           |        |                |
| 18 - 24                       | 92     | 9.2            |
| 25 - 34                       | 180    | 18.0           |
| 35 - 54                       | 312    | 31.2           |
| 55 - 64                       | 194    | 19.4           |
| 65 - 74                       | 132    | 13.2           |
| 75 and above                  | 90     | 9.0            |
| Race                          |        |                |
| White or Caucasian            | 839    | 84.8           |
| African American or Black*    | 123    | 12.4           |
| Hawaiian or other Pacific Islanders | 2  | 0.2            |
| Asian                         | 17     | 1.7            |
| American Indian or Alaska Native | 9  | 0.09           |
| Ethnicity                     |        |                |
| Hispanic                      | 47     | 4.7            |
| Non-Hispanic*                 | 948    | 95.3           |
| Marital status                |        |                |
| Married/ Living together      | 511    | 51.2           |
| (Married or remarried)        | (439)  |                |
| (Member of an unmarried couple)| (72)  |                |
| Single group*                 | 479    | 48.0           |
| (Divorced)                    | (99)   |                |
| (Separated)                   | (9)    |                |
| (Widowed)                     | (50)   |                |
| (Single, never been married)  | (321)  |                |
| Other                         | 8      | 0.8            |
| Children in the house         |        |                |
| Yes*                          | 247    | 24.9           |
| No                            | 744    | 75.1           |
| Employment status             |        |                |
| In labor force                | 493    | 50.1           |
| Not in labor force*           | 492    | 49.9           |
| Income                        |        |                |
| Below $30,000                 | 290    | 29.6           |
| $30,000 to $59,999            | 324    | 33.1           |
| Above $59,999*                | 366    | 37.3           |
| Education                     |        |                |
| ≤ High school graduate        | 374    | 37.4           |
| Some college (less than 4-year)| 315  | 31.6           |
| ≥ College graduate*           | 309    | 31.0           |
| Place of Residence            |        |                |
| Rural community               | 217    | 21.7           |
| Small city or town, village   | 231    | 23.1           |
| A suburb                      | 414    | 41.4           |
| Urban community*              | 129    | 12.9           |
| Other                         | 9      | 0.9            |

Note: * The reference subgroup when the parameter is used as independent variable.

* Cases where the number of responses do not sum to 1,000 are due to non-responses for that particular category.
5.1. Overall behaviors

Prior to the pandemic, survey respondents walked much more frequently for recreation or exercising than for commuting and services (as seen in Fig. 2). About 1 in 7 (13.9 percent) of Michigan adults walked for exercise daily. A quarter (24.9 percent) of the adult population never did. About 3 out of 4 Michigan adults (75.7 percent) never walked to commute while 1 in 12 adults (8 percent) walked to commute daily. About 1 in 3 (35 percent) Michigan adults also walked to access services like stores, restaurants, or other businesses at least once a week. Nine out of ten adults (90.5 percent) in Michigan never used biking as a mode of commuting before the pandemic (as seen in Fig. 3). However, about 1 percent of the population biked to work or school daily. Also, 1 in 15 Michigan adults biked to access services at least once a week. Biking for recreation or exercising was the most popular trip purpose. About 1 in 8 of adults in Michigan biked for recreation or exercising at least once a week.

During the pandemic, 45 percent and 46 percent of the Michigan adults kept the same level of walking and biking, respectively (as seen in Fig. 4). The percentage of increase in walking frequency (22.4 %) was about the same as that of decrease. However, about twice as many respondents biked less frequently (15.5 %) versus more frequently (8.4 %). Contrary to the findings of large urban areas in the United States, overall biking activities decreased in Michigan during the pandemic.

Most people in Michigan planned to keep or increase their walking and biking activities in the future after the pandemic (as seen in Fig. 5). About a third (34.3 percent) of the adult population planned to increase their walking activity and one fifth (19.1 percent) of the adult population planned to increase their biking activity. However, about one in twenty Michigan adults planned to decrease their walking or biking.

5.2. Pre-pandemic walking and biking behavior models

The statistically significant sociodemographic factors related to pre-pandemic walking behaviors are shown in Table 2 and the findings are interpreted below.

- As age increased, Michigan adults were more likely to respond “Almost Never” regarding whether they walked for recreation or commuting. A one-year increase in age was associated with a 2.3 percent and 4 percent increase in the odds of almost never walking for recreation and commuting, respectively.
- White or Caucasian respondents were more likely to have never walked for services, such as going to a store, restaurant, or other business, than African Americans.
- Respondents who live in households below the poverty line (under $30,000 annually) were less likely to walk frequently for services compared to people who are in households above the median income (over $60,000 annually).
- Those who have less than a college degree, including high school degree or less and less than 4-year college, were less likely to either walk frequently to work or never walk to work compared to people who have completed a college degree or more. In other words, these demographics were likely to commute by walking occasionally.
- Those who have some college education (less than 4-year) were more likely to never exercise by walking compared to people who have completed a college degree or more.

Our study shares similar findings as other studies, such as that older people are less likely to walk. However, unlike some earlier studies, our study did not find that people with lower incomes are more likely to walk (Blumenberg, 2009). On the contrary, our study
found that people with less than $30 k annual household income were less likely to walk frequently to services compared to people above the median income. This could be attributed to infrastructure (e.g., sidewalk) or land use (e.g., too far to walk) barriers in Michigan that cause such services to be less accessible to those of lower income. In addition, people with lower education were more likely to commute by walking occasionally compared to people with higher education who were more likely to do it either frequently or almost never.

The statistically significant sociodemographic factors related to pre-pandemic biking behaviors are shown in Table 3 and the findings are interpreted below.

- As age increased, Michigan adults were more likely to respond “Almost Never” regarding whether they biked for recreation or commuting. A one-year increase in age was associated with a 2 percent and 4.7 percent increase in the probability of never biking for recreation and commuting, respectively.
- Male respondents were more likely to bike for recreation than female respondents. The probability of males who never biked for recreation was about half (48 %) of that of females.
- White or Caucasian respondents were 3.1 times more likely to never bike for services compared to African American respondents.
- Those who are married or living together as a couple were less likely to bike frequently for recreation compared to those who are in the single group.
• Those who have no children in the house were approximately 1.9 times more likely to never bike for recreation.

• Those in the labor force were approximately 2 times more likely to bike frequently for recreation than those were not in the labor force and were also approximately 1.7 times more likely to never bike for recreation. In other words, people with a job were more likely to bike for recreation either frequently or almost never.

Our study confirmed the findings from many studies that those who are young, or male are more likely to bike. In addition, household structure (i.e., married or not, living with children or not) and employment status had a significant influence on Michigander’s choice of biking for recreation. Unlike other studies (Braun, 2021), our study did not find that income and education level were associated significantly with biking behaviors before the pandemic. This indicates that factors such as infrastructure, land use, and safety identified in other literature may have played a more significant role than socioeconomic status in bicycling behaviors in Michigan. Similar to the findings in walking behavior, White Americans were more likely to have never biked to services compared to African Americans in Michigan. This could be attributed to the cultural differences as socioeconomic status was not found to be a factor for biking behaviors. It is worth noting that a high unemployment rate, due to the pandemic, was reported at the time of the survey. Employment status before the pandemic was not available from the survey data. Thus, the identified relationship between the employment status and biking behaviors may not hold.

5.3. During-Pandemic walking and biking behavior models

Statistically significant sociodemographic factors related to during-pandemic walking and biking behaviors are shown in Table 4 and the findings are interpreted below.

• As age increased, Michiganders made less changes in their walking behavior during the pandemic. A one-year increase in age was associated with 1.6 percent decrease in the odds of walking less frequently. A one-year increase in age was associated with 3.4 percent decrease in the probability of walking more frequently.

• As age increased, respondents were less likely to increase biking during the pandemic. A one-year increase in age was associated with 1.6 percent decrease in the odds of biking more frequently.

• Those who are of Hispanic origin were more likely to change their walking behaviors during the pandemic. They were approximately 3.5 times more likely to increase their walking and, on the other end, 2.5 times more likely to decrease their walking compared to those who are not of Hispanic origin.

• White or Caucasian respondents were less likely than African American respondents to decrease their biking during the pandemic.

• Those with a High School education or less were less likely to walk more compared to those who have completed college and above degree.

• Those whose household income was below poverty ($30 k), or the median income level ($60 k) were 1.92 or 2.05 times more likely to decrease their biking frequency, respectively, compared to those are in above median income households.

• Those who walked frequently for recreation before the pandemic were approximately 4.8 times more likely to increase their walking during the pandemic.
Table 2
Pre-pandemic Walking Behavior Multinomial Logistic Regression Model Results.

| Variable                  | Recreation or exercising<sup>a</sup> | Almost Never | Going to a store, restaurant, or another business<sup>a</sup> | Almost Never | Commuting to work or school<sup>b</sup> | Almost Never |
|---------------------------|--------------------------------------|--------------|---------------------------------------------------------------|--------------|------------------------------------------|--------------|
|                           | Frequently | Exp (B) |          | Frequently | Exp (B) |          | Frequently | Exp (B) |          | Frequently | Exp (B) |          | Frequently | Exp (B) |          |
| Age                       | 0.000      | 1.000   | 0.022** | 1.023      |         | –0.007 | 0.993     | –0.002 | 0.998   | 0.009      | 1.009   | 0.039** | 1.040      |
| White or Caucasian        | −0.413     | 0.662   | –0.731  | 0.482      |         | 0.533  | 1.703     | 0.777* | 2.175   | 0.423      | 1.527   | 0.720  | 2.055      |
| Below $30,000             | 0.176      | 1.193   | 0.479   | 1.614      |         | –0.592*| 0.553     | –0.501 | 0.606   | –0.143     | 0.867   | –0.389 | 0.677      |
| ≤ High school graduate    | –0.309     | 0.735   | 0.448   | 1.565      |         | 0.076  | 1.078     | –0.149 | 0.862   | –1.195*    | 0.303   | –1.642**| 0.194      |
| Some college              | –0.041     | 0.960   | 0.711*  | 2.035      |         | –0.333 | 0.717     | –0.113 | 0.893   | –1.260*    | 0.284   | –1.262*| 0.283      |
| Intercept                 | 1.891**    | 0.960   | –0.336  | 2.035      |         | 1.432* | 0.904     |         |         | 1.838      | 2.203*  |         |            |
| Observations              | 919        | 919     |         | 918        | 918     |         | 914       | 914     |         | 914        | 914     |         |            |
| –2 Log Likelihood         | 1704.984   |         |         | 1738.321   |         |         | 969.108   | 969.108 |         | 969.108    | 969.108 |         |            |
| Chi-Square                | 110.950    |         |         | 54.308     | 30      |         | 151.130   | 30      |         | 0.000      | 0.000   |         |            |
| df                        | 30         |         |         | 30         |         |         | 30        |         |         | 0.000      |         |         |            |
| Sig.                      | 0.000      |         |         | 0.004      |         |         | 0.214     |         |         | 0.214      |         |         |            |
| Nagelkerke                | 0.132      | 0.132   |         | 0.067      | 0.067   |         | 0.214     |         |         | 0.214      |         |         |            |

Note: <sup>a</sup> The reference category is: Occasionally
<sup>b</sup> Correlation is significant at the 0.05 level. ** Correlation is significant at the 0.01 level.
| Variable                  | Recreational or exercising | Almost Never | Going to a store, restaurant, or another business | Almost Never | Commuting to work or school | Almost Never |
|--------------------------|---------------------------|--------------|--------------------------------------------------|--------------|----------------------------|--------------|
|                          | Frequently                | Exp (B)      | Frequently                                      | Exp (B)      | Frequently                  | Exp (B)      |
| Age                      | 0.000                     | 1.000        | 0.020*                                          | 1.020        | 0.006                      | 0.994        |
| Male                     | -0.110                    | 0.896        | -0.733**                                       | 0.480        | -0.122                     | 0.885        |
| White or Caucasian       | -0.639                    | 0.528        | 0.001                                           | 0.999        | 0.774                      | 2.168        |
| Married/Living together  | -0.796*                   | 0.451        | 0.032                                           | 0.969        | 0.233                      | 1.262        |
| Children not in the house| -0.089                    | 0.915        | 0.651*                                          | 1.917        | 0.257                      | 1.293        |
| In labor force           | 0.694*                    | 2.002        | 0.553*                                          | 1.739        | -0.035                     | 0.965        |
| Intercept                | 0.587                     | 0.752        | 0.406                                           | 1.639*       | 0.260                      | 1.293        |
| Observations             | 901                       | 901          | 903                                             | 903          | 904                        | 904          |
| -2 Log Likelihood        | 1070.271                  | 799.808      | 445.457                                        | 445.457      | 445.457                    | 445.457      |
| Chi-Square               | 97.133                    | 45.942       | 71.689                                         | 71.689       | 71.689                     | 71.689       |
| df                       | 30                        | 30           | 30                                              | 30           | 30                         | 30           |
| Sig.                     | 0.000                     | 0.031        | 0.000                                           | 0.000        | 0.000                      | 0.000        |
| Nagelkerke               | 0.140                     | 0.140        | 0.081                                           | 0.081        | 0.173                      | 0.173        |

Note: * The reference categories are: Occasionally

* Correlation is significant at the 0.05 level. ** Correlation is significant at the 0.01 level.
Those who biked frequently for recreation before the pandemic were more likely to change by either increasing or decreasing their biking during the pandemic.

Those who walked occasionally for recreation before the pandemic were more likely to change by either increasing or decreasing their walking.

Those who biked occasionally for recreation before the pandemic were more likely to increase their biking during the pandemic.

Those who walked frequently for services before the pandemic were approximately 1.8 times more likely to decrease their walking during the pandemic.

Those who biked frequently for services before the pandemic were less likely to decrease their biking during the pandemic.

Those who walked occasionally for services before the pandemic were more likely to change by either increasing or decreasing their walking.

Those who walked frequently for commuting before the pandemic were less likely to increase their walking during the pandemic.

The during-pandemic model results show that COVID-19 impacted walking and biking behaviors differently. Those who are older, or with lower income or education levels, or of color tended to reduce their walking and biking activities during the pandemic. Adverse living, economic, or personal factors, which were more significant among these groups, could have contributed to the reduction. These factors could include, but are not limited to, a lack of access to walking/biking infrastructure, reduced time due to being essential

Table 4
During-pandemic Walking and Biking Behaviors Multinomial Logistic Regression Results.

| Variable                          | Walking During-pandemic | Biking During-pandemic |
|-----------------------------------|-------------------------|------------------------|
|                                   | Decreased | Exp (B) | Increased | Exp (B) | Decreased | Exp (B) | Increased | Exp (B) |
| Age                               |           |         |           |         |           |         |           |         |
| White or Caucasian                | −0.016*** | 0.984   | −0.034*** | 0.966   | 0.010    | 1.010   | −0.023*   | 0.977   |
| Hispanic                          | 0.911*    | 2.486   | 1.258**   | 3.519   | 0.228    | 1.256   | −0.092    | 0.912   |
| Below $30,000                     | 0.219     | 1.245   | −0.298    | 0.743   | 0.652*   | 1.920   | 0.036     | 1.037   |
| $30,000 to $59,999                | 0.360     | 1.433   | 0.018     | 1.018   | 0.719*** | 2.053   | −0.163    | 0.849   |
| ≤ High school graduate            | −0.076    | 0.927   | −0.529*   | 0.589   | 0.395    | 1.484   | 0.496     | 1.642   |
| Pre-COVID frequently for recreation | 0.049   | 1.050   | 1.570**   | 4.805   | 1.139**  | 3.125   | 2.396**   | 10.984  |
| Pre-COVID occasionally for recreation | 0.893** | 2.442   | 0.962**   | 2.617   | 0.180    | 1.197   | 1.757**   | 5.796   |
| Pre-COVID frequently for services  | 0.585*    | 1.795   | 0.416     | 1.516   | −1.530*  | 0.216   | 0.205     | 1.227   |
| Pre-COVID occasionally for services | 0.722*   | 2.059   | 0.664*    | 1.942   | 0.309    | 1.361   | 0.184     | 1.202   |
| Pre-COVID frequently for commuting | −0.399  | 0.671   | −0.745*   | 0.475   | 0.338    | 1.402   | −0.723    | 0.485   |
| Interception                      | −0.250    | 0.015   | −1.391*   | −1.104  |          |          |           |         |
| Observations                      | 812       | 812     |           | 633     |           | 633     |           |         |
| −2 Log Likelihood                | 1486.576  | 922.200 |           |         |           |         |           |         |
| Chi-Square                        | 185.332   | 138.140 |           |         |           |         |           |         |
| df                                | 42        | 42      |           |         |           |         |           |         |
| Sig.                              | 0.000     | 0.000   |           |         |           |         |           |         |
| Nagelkerke                        | 0.234     | 0.234   |           | 0.241   |           | 0.241   |           |         |

Note: * The reference category is: About the same.
** Correlation is significant at the 0.01 level.
Table 5
Future Walking and Biking Anticipations Multinomial Logistic Regression Results.

| Variable                          | Walking Future Anticipation | Biking Future Anticipation |
|-----------------------------------|----------------------------|---------------------------|
|                                   | Plan to decrease | Exp (B) | Plan to increase | Exp (B) | Plan to decrease | Exp (B) | Plan to increase | Exp (B) |
| Age                               | −0.020       | 0.980   | −0.021*** | 0.980   | −0.027*  | 0.973   | −0.042**   | 0.959   |
| ≤ High school graduate            | −0.129   | 0.879   | −0.343    | 0.710   | −0.064   | 0.938   | −0.676*    | 0.509   |
| Some college                      | −0.375   | 0.687   | −0.444*   | 0.641   | −0.497   | 0.608   | −1.017**   | 0.362   |
| During-COVID decreased            | 1.263** | 3.535   | 1.417**   | 4.124   | 0.840    | 2.317   | 1.917**    | 6.799   |
| During-COVID about the same       | −0.340  | 0.712   | −0.668**  | 0.498   | −0.643   | 0.526   | −0.439     | 0.644   |
| Intercept                         | −0.500    | 1.966** |           |         | 0.909    | 1.707** |           |         |
| Observations                      | 741       | 741     |           | 572     |           | 572     |           |         |
| −2 Log Likelihood                | 1100.949  | 757.483 |           |         |           |         |           |         |
| Chi-Square                        | 162.102   | 152.768 |           |         |           |         |           |         |
| df                                | 34        | 34      |           |         |           |         |           |         |
| Sig.                              | 0.000     | 0.000   |           |         |           |         |           |         |
| Nagelkerke                        | 0.240     | 0.240   |           | 0.294   |           | 0.294   |           |         |

Note: * The reference category is: Don’t plan to change.
** Correlation is significant at the 0.01 level.
workers or taking care of children no longer in daycare or school, fears of going out, underlying health conditions, loss of jobs or health insurance, or reduced public transit service.

In addition to sociodemographic factors, pre-pandemic walking and biking habits exacerbated the impact on walking and biking during the pandemic. People who walked frequently for recreation before the pandemic were likely to walk even more during the pandemic. However, people who walked frequently for services and commuting before the pandemic decreased their activities during the pandemic. This reduction could largely be due to the Stay-at-home order, closure of services and businesses, or loss of jobs. In general, people who biked before the pandemic, regardless of the purpose and frequency, were likely to increase their biking activities during the pandemic. The exception was those who biked frequently for recreation before the pandemic where some increased and some decreased their biking during the pandemic.

5.4. Future walking and biking anticipations models

Statistically significant sociodemographic factors related to future walking and biking anticipations are shown in Table 5 and the findings are interpreted below.

- As age increased, respondents were less likely to anticipate walking more in the future. A one-year increase in age was associated with 2 percent decrease in the odds of walking more in the future.
- Those who have some college education (less than 4-year college) were less likely to increase their walking in the future compared to those with higher levels of education.
- Those who have some college education or less were less likely to increase their biking in the future compared to people who have higher levels of education.
- Those who have decreased their walking during the pandemic anticipated to change their behaviors by either increasing or further decreasing their walking in the future.
- Those who have decreased their biking during the pandemic were anticipated to increase their biking in the future.
- Those who have maintained the same level of walking during the pandemic were less likely to increase their walking in the future.

Sociodemographic factors also influenced anticipated post-pandemic behaviors. Older people or people with lower education level were less likely to increase their walking and biking in the future. Those who decreased their biking during the pandemic planned to increase their biking activities in the future. However, some of those who decreased walking during pandemic planned to decrease even more in the future. It is worth noting that the survey was conducted during the second wave of COVID-19 with no vaccine available at the time. Fear and health concerns could be the reasons for those planning to reduce walking and biking in the future.

5.5. Significant sociodemographic factors

Significant sociodemographic factors and their effects on walking or biking behaviors were summarized in Table 6. Age, race, income, and education level were among the most consistent influencing factors for both walking and biking behaviors. Gender, marital status, children in the house, and employment status were factors that appear only associated with biking behaviors.

6. Conclusion

The online survey conducted in November 2020 collected responses from 1,000 randomly selected Michigan residents statewide regarding walking and biking behaviors before and during the COVID-19 pandemic, as well as their anticipated future behaviors. This study revealed differing impacts of the COVID-19 pandemic on walking and biking behaviors among various sociodemographic groups.

A series of multinominal logistic regression models revealed that people from underprivileged sociodemographic groups, such as those who are older or have lower education or income level, were less active in general before the pandemic, and these walking and biking behavior gaps were exacerbated by the pandemic. Furthermore, the negative impact for these groups were anticipated to continue in the future.

Besides age, income, and education level, race was also found to be related to walking and biking behaviors. Prior to the pandemic, White Americans were more likely to have never walked or biked for services compared to African Americans in Michigan. In absence of income and education factors for pre-pandemic biking behavior, this behavior choice could be related to cultural difference. However, during the pandemic, White Americans were more likely to maintain and increase biking activities than African Americans. This behavior change reveals the disparate impact of the pandemic on people of color.

Our study did not find significant relationships between the 4-level transect “Place of Residence” variable and walking/biking behaviors. As mentioned in the background, comparatively speaking, Michigan has sprawling land use and relatively low urban population densities. Many urban and suburban communities also lack walking and biking infrastructure. More detailed information such as presence of sidewalks, bike lanes, wheelchair ramps are needed to capture the relationship between built environment and walking/biking behaviors in Michigan.

Prior habits were found to influence during- and post-pandemic walking or biking behaviors. People who walked or biked frequently for recreation or exercise before the pandemic were likely to increase their activities during the pandemic. However, service or commuting related walking was mostly reduced during the COVID-19 pandemic, which could largely be explained by several
| Sociodemographic Factors | Effects on Walking                                                                 | Effects on Biking                                                                 |
|--------------------------|-----------------------------------------------------------------------------------|----------------------------------------------------------------------------------|
| **Pre-Pandemic**         |                                                                                   |                                                                                  |
| Age                      | Negative with increasing age for recreation or commuting                           | Negative with increasing age for recreation or commuting                           |
| Gender                   | -                                                                                 | Positive with Male for recreation                                                |
| Race                     | -                                                                                 | Negative with Whites for services                                                |
| Income                   | Positive with increasing income for services                                       | -                                                                               |
| Education level          | • Positive with increasing education for recreation                                |                                                                                  |
|                          | • Divergent with increasing education for commuting: either frequently or never     |                                                                                  |
|                          | • Convergent with decreasing education for commuting: neither frequently nor never  |                                                                                  |
| Marital status           | -                                                                                 | Negative with Married for recreation                                              |
| Children in the house    | -                                                                                 | Positive with Children in the house for recreation                                |
| Employment status        | -                                                                                 | • Divergent with in Labor force for recreation: either frequently or never        |
|                          |                                                                                  | • Convergent with not in Labor force for recreation: neither frequently nor never  |
| **During-Pandemic**      | Convergent with increasing age: neither increase nor decrease                     | Negative with increasing age                                                     |
| Age                      | Divergent with Hispanic: either increase or decrease                                | -                                                                               |
| Ethnicity                | -                                                                                 | Positive with Whites                                                              |
| Race                     | -                                                                                 | Positive with increasing Income                                                   |
| Income                   | -                                                                                 |                                                                                  |
| Education level          | Positive with increasing education                                                |                                                                                  |
| **Future**               |                                                                                   |                                                                                  |
| Age                      | Negative with increasing age                                                      | Convergent with increasing age: neither increase nor decrease                    |
| Education level          | Positive with increasing education                                                | Positive with increasing education                                               |

Note: "-" indicates that the factor was not found to be significant.
pandemic-related factors, including the stay-at-home order, closure of services, loss of jobs, or reduction in public transit service.

Policies are needed to mitigate the negative impact by COVID-19 and cultivate a more active lifestyle long term. Complete Streets, Context Sensitive Solutions, Safe Route to School, and promoting public transit use are among the policies being considered and implemented in Michigan. Those communities with a higher percentage of elderly residents, people of color, or people of lower income or education level should be targeted due to the disparate impact of the pandemic in walking and biking behaviors found by this study. Further studies are needed to understand the barriers that prevented certain demographics from walking or biking more. These barriers could include personal (e.g., lack of free time), infrastructural (e.g., lack of sidewalk or bike lane) or safety related factors.

A few limitations exist for this study. Although trip purpose was considered as a factor for pre-pandemic walking and biking behaviors, it was omitted in the survey questions for behaviors during the pandemic and anticipated after the pandemic. Consequently, cross-purposes behavior changes (e.g., from commuting to recreation) cannot be investigated. In addition, the reasons for walking and biking behavior changes were not collected in the survey. Therefore, the behavior choices associated with certain demographics could not be fully explained by this study. Understanding the reasons behind certain walking and biking behaviors could further inform decision makers and transportation officials when planning and investing in inclusive and equitable walking and biking infrastructure.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data will be available on this site soon: http://ippsr.msu.edu/survey-research/state-state-survey-soss/soss-data

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