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Impacts of commute mode on body mass index: A longitudinal analysis before and during the COVID-19 pandemic

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ABSTRACT

Introduction: COVID-19 has impacted millions of commuters by decreasing their mobility and transport patterns. While these changes in travel have been studied, less is known about how commute changes may have impacted individuals' body mass index (BMI). The present longitudinal study explores the relationship between commute mode and BMI of employed individuals in Montréal, Canada.
Methods: This study uses panel data drawn from two waves of the Montréal Mobility Survey (MMS) conducted before and during the COVID-19 pandemic (n = 458). BMI was modeled separately for women and men as a function of commuting mode, WalkScore©, sociodemographic, and behavioral covariates using a multilevel regression modeling approach.
Results: For women, BMI significantly increased during the COVID-19 pandemic, but telecommuting frequency, and more specifically telecommuting as a replacement of driving, led to a statistically significant decrease in BMI. For men, higher levels of residential local accessibility decreased BMI, while telecommuting did not have a statistically significant effect on BMI.
Conclusions: This study's findings confirm previously observed gendered differences in the relations between the built environment, transport behaviors, and BMI, while offering new insights regarding the impacts of the changes in commute patterns linked to the COVID-19 pandemic. Since some of the COVID-19 impacts on commute are expected to be lasting, findings from this research can be of use by health and transport practitioners as they work towards generating policies that improve population health.

1. Introduction

The COVID-19 pandemic has impacted societies around the world since its onset in late 2019. To slow the spread of COVID-19 governments adopted various policies, such as lockdowns and stay-at-home orders, which led to radical changes in mobility and transport patterns. In Canada, lockdowns were implemented throughout the country, which led to schools and workplaces to either temporally shutdown or move online (Haider and Anwar, 2022). Overall, the pandemic has directly reduced commuting by favorizing remote activities, with 40% of Canadian workers telecommuting – e.g., working from home – in April 2020 (Mehdi and Morissette,

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2021). Telecommuting remained restricted to specific types of jobs as many front-line and essential workers (e.g., healthcare, transport, construction, retail, or hospitality) continued to require in-person presence (Haider and Anwar, 2022).

Previous research has asserted telecommuting has both positive and negative consequences for one's health. Telecommuting has been associated with a healthier work life balance and emotional wellbeing, as well as increases in public and active transit usage (Chakrabarti, 2018). Yet, telecommuting has also been associated with loneliness (Chakrabarti, 2018), as well as increased stress and overwork (Tajalli and Hajbabaie, 2017). The effects of telecommuting on one's health are therefore varied and not fully understood both prior to and during COVID-19.

As such, the purpose of this paper is to understand how the health of employed Canadians – as modeled through Body Mass Index (BMI) – was affected by commute changes that happened during the COVID-19 pandemic. Specifically, we explore the effect of telecommuting on workers' BMI. Additionally, we explore this effect based on the transport mode that the worker was using previous to telecommuting. The impact of the residential built environment on BMI is also considered, as variables such as local accessibility and access to amenities have been routinely linked to lower BMIs (Wasfi et al., 2016a, 2016b, 2017). Using panel data from the Montréal Mobility Survey (MMS) (n = 458), this paper examines how the modal shift to telecommuting affects BMI while controlling for neighborhood-built environment and individual socio-demographics. In doing so, we aim to contribute to the literature on the indirect health impacts of the COVID-19 pandemic on individuals.

The remainder of the paper is structured as follows: Section 2 reviews the existing literature related to travel behavior effects on physical health, and more specifically on BMI; Section 3 presents a detailed description of the data and methods used in this study; Section 4 presents the results obtained by the analyses performed; Section 5 discusses the results and their policy implications; Section 6 concludes the analyses and main takeaways from the study; and Section 7 presents future lines of study which would build on the presented results.

2. Literature review

Health is influenced by a plurality of determinants amongst which are environmental conditions, social circumstances, and behavioral patterns (McGovern et al., 2014). In recent years, planners and policymakers have been focusing more on improving the built environment and promoting health behaviors of urban residents to improve population-wide health (Azzopardi-Muscat et al., 2020). BMI – calculated by dividing one's weight in kilograms by the square of their height in meters – is a common measure of population health (Gutin, 2018; Nuttall, 2015). High BMIs (35 >) have been consistently linked to elevated mortality and chronic illnesses (Armour et al., 2013; Gutin, 2018). Research has revealed that the validity of this measure varies across age, gender, and ethnicity (Buss, 2014), and cannot discriminate between body fat and lean mass, resulting in athletes and muscular individuals often diagnosed as obese (Lopez-Jimenez and Miranda, 2010; Romero-Corral et al., 2008). While having a high BMI on its own does not correspond with higher risk of mortality or chronic diseases at the individual level, it can be used in research as a measure of obesity at the population level (Gutin, 2018; Nuttall, 2015).

The built environment, particularly the walkability of a neighborhood, has been shown to have a significant relationship with BMI. Walkability encompasses multiple dimensions, such as local access to amenities, connectivity, land-use density, and perceptions of safety and comfort on the street (Hajna et al., 2013, 2015; Herrmann et al., 2017; Jensen et al., 2017; Rodrigue et al., 2022). Local accessibility – a subcomponent of walkability – has been a common variable used in relation to BMI. In past research, higher levels of residential local accessibility has been linked to lower BMIs in adults (Tarlov et al., 2020). In Canada, pedestrian accessibility was found to be positively linked to elevated levels of walking for utilitarian purposes in urban areas (Wasfi et al., 2016a, 2017). Specifically, in Montréal, living in a walkable area was shown to slow age-related weight gain in men (Wasfi et al., 2016b). Additionally, accessibility to healthy food choices is particularly important regarding BMI as it influences eating behaviors (Murphy et al., 2017, 2018; Sacks et al., 2019). Overall, the built environment's association with BMI has shown to be mediated by its ability to dictate individuals' range of choices regarding physical activity and eating habits, resulting in population-level changes in health.

The relationship between transport patterns and health outcomes – including BMI – has been widely studied (Janatabadi and Ermagun, 2022; Saunders et al., 2013). In particular, past research has focused on the effects of transport mode use on physical health. Past works have highlighted the beneficial impact of active modes of transport (e.g., walking and cycling) on health as it increases physical activity levels (de Haas et al., 2021; Lee and Buchner, 2008) and has been shown to promote a decrease in BMI (Compernolle et al., 2016; Kitchen et al., 2011). The health benefits of public transport usage are partly linked to active transport to and from transit stops (Durand et al., 2016; Langlois et al., 2016; Ravensbergen et al., 2022b; Xiao et al., 2019). The distance walked to public transport contributes to attain the recommended daily amount of physical activity across multiple North American cities (Langlois et al., 2016; Ravensbergen et al., 2022b; Veillette et al., 2018). In contrast, private motorized transport has been associated with higher BMIs across multiple contexts (Dons et al., 2018; Pendola and Gen, 2007; Sun et al., 2017).

In the case of workers, a component of daily travel which has been shown to have relevant effects on health is travelling to work, or *commuting* (Jacob et al., 2021). Longer commuting times have been associated with increased prevalence of obesity in workers (Sha et al., 2019), as well as with increased levels of stress (Zhu et al., 2020). Commuting mode choice has also shown to have relevant impacts on workers' health. In this context, commuting in active modes of transport has been associated to enhanced worker health (Shephard, 2008). Similarly, when compared to commuting by car, travelling to work by public transit is associated to higher rates of physical activity (Wasfi et al., 2013) and lower obesity rates (Tajalli and Hajbabaie, 2017).

While the built environment and transport patterns have effects on individual behaviors and BMI, socioeconomic and demographic characteristics are also important determinants of health and BMI. In Canada, past scholarship has highlighted the protective effect of recent international immigrants' pre-immigration lifestyle on their health, leading to lower BMI values (Orpana et al., 2010; Wasfi et al., 2016b). Gender has also been shown to be an important variable in BMI studies as men tend to have higher BMIs on average than women (Buss, 2014; Nuttall, 2015), and gendered interactions with other variables have been observed (Guilcher et al., 2017; Wasfi et al., 2016b). Previous studies have also found that BMI increased with age, with this relationship being subject to variations depending on other individual and environmental factors (Carthy et al., 2020; Li et al., 2008; Mathis et al., 2017). Lastly, adults with high (>30) and extremely low (<18.5) BMIs have been shown to be at a higher risk of developing mobility-impairing disabilities (Armour et al., 2013; Ferraro et al., 2002).

In addition to the multiple factors already discussed, changes at the societal level can impact individuals' health. This is the case of the COVID-19 pandemic and the associated public policies which have been linked to primarily negative effects on BMI through deterioration of eating habits and decrease in physical activity in two cross sectional studies (Akter et al., 2022; Flanagan et al., 2021). The COVID-19 pandemic forced a large segment of the working population to telecommute due to lockdowns. Before the pandemic, telecommuting had been linked to increases in active transport and physical activity, as well as perceived improvements in work-life balance (Chakrabarti, 2018) in addition to positive impacts on general health (Lunde et al., 2022; Oakman et al., 2020). Nevertheless, studies have also shown that telecommuting is associated with social isolation and unhealthy eating habits in Japan (Kubo et al., 2021) as well as increased sedentary time (Kooshari et al., 2021). A recent study has provided added insight on these varying effects, highlighting that changes in active travel behavior when telecommuting are mediated by local accessibility around workers' home, with those living in highly-walkable areas seeing increases in active mode use for non-work purposes when telecommuting (Victoriano-Habit and El-Geneidy, 2023).

The impacts of increased telecommuting during the COVID-19 pandemic on BMI are not well known. Most studies on BMI are cross-sectional, making it hard to confirm any relation to the COVID-19 pandemic and the increased telecommuting. It is important to note that the effects of conventional telecommuting (i.e. before the pandemic) on health are not clearly recognized either due to sparse research. In contrast, research on the effects of the built environment, behavioural choices, and sociodemographics on BMI have been explored extensively, yet the impacts of these variables on BMI during the COVID-19 pandemic is still in its infancy. Therefore, this paper seeks to contribute to the transport and public health literature by exploring the effects of telecommuting on individuals' health, in the context of the COVID-19 pandemic, as modeled through BMI using a longitudinal design.

3. Data and methods

3.1. *Survey tool*

This study uses panel data collected through two-waves of the Montréal Mobility Survey (MMS). The MMS is a multi-year survey conducted by the Transportation Research at McGill (TRAM). The MMS collects data on the travel behaviors and transport perceptions of people 18 years of age and older in Montréal, Canada. In addition, sociodemographic, economic, and physical characteristics were also collected.

Following Dillman et al. (2014), multiple recruitment methods were applied during both waves to ensure a large and representative sample. Half of the survey participants were first recruited through a marketing company. The other half were recruited through a social-media advertising campaign, as well as through fliers distributed randomly at houses in the areas near the projects, and through invitation emails sent to various mailing lists in the region. The first wave of the MMS, conducted in Fall (2019) (pre-COVID-19 pandemic), had 3533 valid respondents while the second wave, collected in Fall (2021) (during the COVID-19 pandemic), had 4063. Out of these valid responses, 950 respondents participated in both waves of the survey after being re-contacted through an invitation email. This study focuses only on the two-wave panel sample of the MMS, meaning those participants who answered the survey both in 2019 and 2021.

Both waves underwent the same data cleaning process to ensure consistency. We removed responses that were filled too quickly to

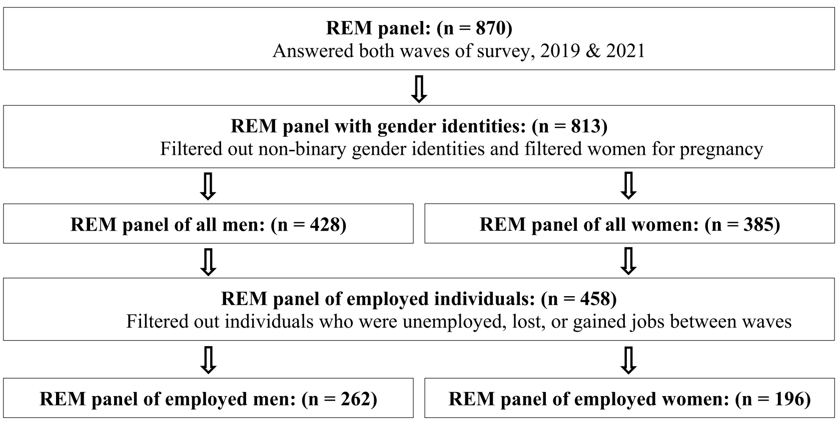

Fig. 1. Data filters used to derive the analytical sample.

be considered reliable, excluding the fastest 5% of responses. Other exclusion criteria included having identical e-mail or IP address within a given wave, invalid age and height changes between waves, and having home, work, or school location outside the Montréal CMA. Following this process, a panel of 870 respondents with valid survey responses in both waves was available. Through the two waves, we collected information on pre-pandemic and current behavior, allowing us to examine the effects of COVID-19 on commuting and health. Further inclusion/exclusion criteria for this study are described in Fig. 1. First, due to a low representation of people identifying as non-binary (n = 21), only responses given by respondents identifying as women or men in the sample were analyzed, with other gender identities filtered out. Additionally, due to the impact of pregnancy on women's BMI, women that had children under the age of 6 in either 2019 or 2021 (either wave), and were of reproductive age (18–45 years old) were filtered out (n = 36). To specifically look at the impact of telecommuting on BMI, respondents were further filtered to include only those who were employed during both waves. This resulted in a final sample of 196 women and 262 men. This dataset size is comparable to previously published studies on the relationship between travel behavior and BMI (Berry et al., 2010; Brown et al., 2017).

Although multi-period datasets, such as the one used in this study, are more complex and expensive to collect than cross-sectional data, their use is highly-recommended in the travel behavior literature (van de Coevering et al., 2015). This is because panel designs allow to measure *change* and *causality* rather than only *differences* and *associations.* In fact, to measure BMI *changes* in time and the factors affecting it, datasets collected for the same group of participants through time are required. For this reason, multi-period designs have been used in several previous BMI studies (Berry et al., 2010; Brown et al., 2017; Jacob et al., 2021).

3.2. Measures/variables

The outcome measure in this study is the BMI. BMI is calculated by dividing one's weight in kilograms by their height in meters squared, both of which were self-reported in each wave. For the models, BMI is treated as a continuous variable, as BMIs were normally distributed for both women and men in our sample.

The primary exposures of interest in this study are the residential WalkScore© and telecommuting frequency. WalkScore© is a composite index ranging from 0 to 100 that reflects the distance to 13 types of amenities by walking. This measure of local accessibility has been tested repeatedly in the land use and transport literature (Hall and Ram, 2018), showing reliability as a walkability indicator (Manaugh and El-Geneidy, 2011). WalkScore© was collected by an API in both waves of the survey for all respondents' home location. For modelling, we subdivided the WalkScore© values into quartiles, following the methodology used in a previous study set in Montréal (Wasfi et al., 2016b). For the Greater Montréal Area, these four quartiles subdivide into: low-walkable neighborhood (0–39), low-medium-walkable neighborhood (40–55), medium-high-walkable neighborhood (56–69), and high-walkable neighborhood (70–100). Telecommuting was defined as working from a remote location, such as one's home or a café rather than commuting to one's primary work location. Number of days telecommuted per week (0–7) were then recorded for each respondent that mentioned partaking in this practice. Furthermore, respondents were asked in both waves for their main mode of commuting to work which was recorded as either car, active (cycling or walking) or transit commutes.

Additionally, each of our models controlled for the following individual socioeconomic characteristics: age, income, education, ethnicity, marital status, disability, having children, and immigration status. In previous studies, all of these personal characteristics have shown to affect an individual's BMI (Berry et al., 2010; Sanchez-Vaznaugh et al., 2008). Other variables included in our models which previous studies have shown to influence BMI are: frequency of vigorous physical activity (Akter et al., 2022), and satisfaction with general health (Yin et al., 2020).

3.3. Analysis

To understand the factors influencing BMI levels during the COVID-19 pandemic, we estimated two sets of weighted multi-level linear regressions with BMI as the dependent variable. Regression models are commonly employed to study BMI using panel data as they allow to isolate the effects of changes in multiple key factors over time while controlling for other unchanging variables (Berry et al., 2010; Carthy et al., 2020; Orpana et al., 2010; Wasfi et al., 2016b). All models were estimated in R version 4.1.1 (R Core Team, 2022) using the lme4 R package (Bates et al., 2015). As in previous studies (Guilcher et al., 2017; Wasfi et al., 2016b), each set of models was stratified by sex, estimating one model for the women sample and one for men, given that biological differences between women and men have been shown to affect their BMI (Campbell, 2016; Wisniewski and Chernausek, 2009). Even though the data from the MMS records gender, since 99.67% of the Canadian population is identifying as cis-gendered (Statistics Canada, 2022), a generalizable trend can be inferred by assuming sex is concordant to self-declared gender for this analysis.

The separation into two distinct sets of models was made to allow for an analysis of different dimensions relating to telecommuting. For the first set of models, the main purpose was to analyze the effect of telecommuting and local accessibility on BMI levels for women and men. For this purpose, we included weekly telecommuting frequency and home-location WalkScore© as the main independent variables while controlling for socioeconomic and demographic as well as health perception. In our second set of models, we further inquired into if the effect of telecommuting on BMI levels varied by the original transport mode that the telecommute was replacing, using an interaction term (between the number of days telecommuted and the main mode of commute). The interaction term could not have been added in the first set of models as it would have been highly correlated with the number of days telecommuted, thus justifying the separation into two sets of models.

In both set of models, we tested variables concerning individual behaviours such as active transport and work physical activity, and residential self-selection factors. However, these factors were excluded from both sets of models, as they were not statistically significant and did not improve the fit of the model. However, while income is not statistically significant, it was still included in both sets of models as it increases the marginal and conditional R-squared. All other control variables, mentioned above, were found to be significant for at least women or men.

To account for the two-wave panel structure of our data, both of our model sets use a two-level approach, with the individual-level as higher level, and the individual-wave-level as lower level. In this sense, the dataset is introduced in its long format, meaning that each row represents one time point per individual. Thus, the models' person-level random effects control for the fact that observations in the two waves are linked to the same individuals. Additionally, all models were weighted to ensure that the results are not biased by over- or underrepresented groups within our sample. The weights were calculated for all valid responses in the panel using the anesrake R package (Pasek, 2018) to match our sample to census tract information of age, income, and gender from Statistics Canada's 2016 census (Statistics Canada, 2016), retrieved through the cancensus R package (von Bergmann et al., 2021).

4. Results

4.1. Descriptive statistics

Table 1 presents a description of our sample in terms of their sociodemographic characteristics and modelling variables. These values not only summarize the description of our sample, showing ample variability among all relevant characteristics, but the value ranges of each variable serve as an indication for the applicability ranges for the estimated models. Fig. 2 presents the geographical location of our sample of 458 employed women and men in the Montréal CMA. This map shows the spatial variability of our sample in terms of residential built environment as measured by WalkScore© and distance to rapid transit.

As seen in Table 1, although the age range of participants in the Montréal Mobility Survey is 18–90 years of age, the age range of the sample considered in this study is reduced to 19–77 years. This is because this study focuses only on respondents who were employed both in 2019 and 2021, which is also why most participants are in the 35 to 54 age range. Our descriptive analysis reveals that the average BMI for both women and men, in both waves, is in the overweight category (BMI 25–30). The 196 women had a mean BMI of 26.2 (SD = 5.9) in 2019, and 26.6 (SD = 6.4) in 2021. The proportion of employed women who were overweight or obese (BMI >25) was 48% in 2019 and 50% in 2021. The 262 men had a mean BMI of 27.1 (SD = 5.1) in both 2019 and 2021 (SD = 5.5). The proportion of employed men who were overweight or obese (BMI >25) was 66% in 2019 and 64% in 2021.

Telecommuting frequency increased considerably during the pandemic. Women increased their average number of telecommuting days from 0.5 to 2.4 weekly days, while men increased from 0.7 to 2.7 weekly days. In terms of commuting modes in year 2019, pre-COVID-19, 35% and 43% of women and men, respectively, telecommuted at least one day per week. This increased to 62% for women,

Table 1
Characteristics of employed women and men by survey wave.

Variable	Variable Explanation	Range	Wave 1 (2019)		Wave 2 (2021)	
			Women	Men	Women	Men
			Mean (SD) or %	Mean (SD) or %	Mean (SD) or %	Mean (SD) or %
Body mass index (BMI)	Weight (kg) divided by height (m^2)	*[12–65]*	26.2 (5.9)	27.1 (5.1)	26.6 (5.2)	27.1 (5.5)
Age in 2019	Years of age at baseline	*[19–77]*				
	19–34 years		36.7%	22.1%	36.7%	22.1%
	35–54 years		46.9%	59.2%	46.9%	59.2%
	55 or more years		16.3%	18.7%	16.3%	18.7%
WalkScore©	WalkScore© of home location	*[0–100]*	59 (27.1)	57 (27.7)	58 (27.0)	58 (27.3)
Immigration Status	Born in Canada.	*[1 = yes]*	77.8%	69.7%	77.8%	69.7%
Transportation disability	Daily transportation needs are affected by one's disability	*[1 = yes]*	4.1%	3.8%	6.6%	5.7%
Income	Sorted into six income brackets of income in CAD:					
	0-30,000		6.1%	4.6%	3.1%	2.7%
	30,001–60,000		24.5%	20.6%	15.3%	14.5%
	60,001–90,000		26.5%	17.6%	28.1%	21.4%
	90,001–120,000		18.4%	22.1%	25.0%	17.2%
	120,001–150,000		13.3%	13.0%	12.2%	19.1%
	150,001+		11.2%	22.1%	16.3%	25.2%
Life satisfaction of gen. health	Satisfaction of one's general health.	*[0–10]*	7.4 (2.0)	7.3 (1.9)	7.0 (1.9)	7.0 (1.9)
Physical activity	Weekly days of vigorous sports	*[0–7]*	1.5 (1.7)	1.4 (1.9)	1.2 (1.6)	1.2 (1.7)
Telecommute	Weekly days of tele-commuting	*[0–7]*	0.5 (1.2)	0.7 (1.4)	2.4 (2.2)	2.7 (2.2)
Telecommuter	Telecommutes at least one day per week	*[1 = yes]*	35.2%	43.1%	62.2%	64.5%
Main mode of commute	Type of commute mode:					
	Car – individual vehicle, rideshare, taxi.		29.1%	31.3%	27.6%	26.7%
	Active – bike, walk, Bixi (paid bikeshare).		13.2%	17.2%	14.3%	16.4%
	Transit – metro, bus, commuter rail, paratransit.		48.0%	40.8%	16.3%	15.6%

Note. 1 SD = standard deviation.

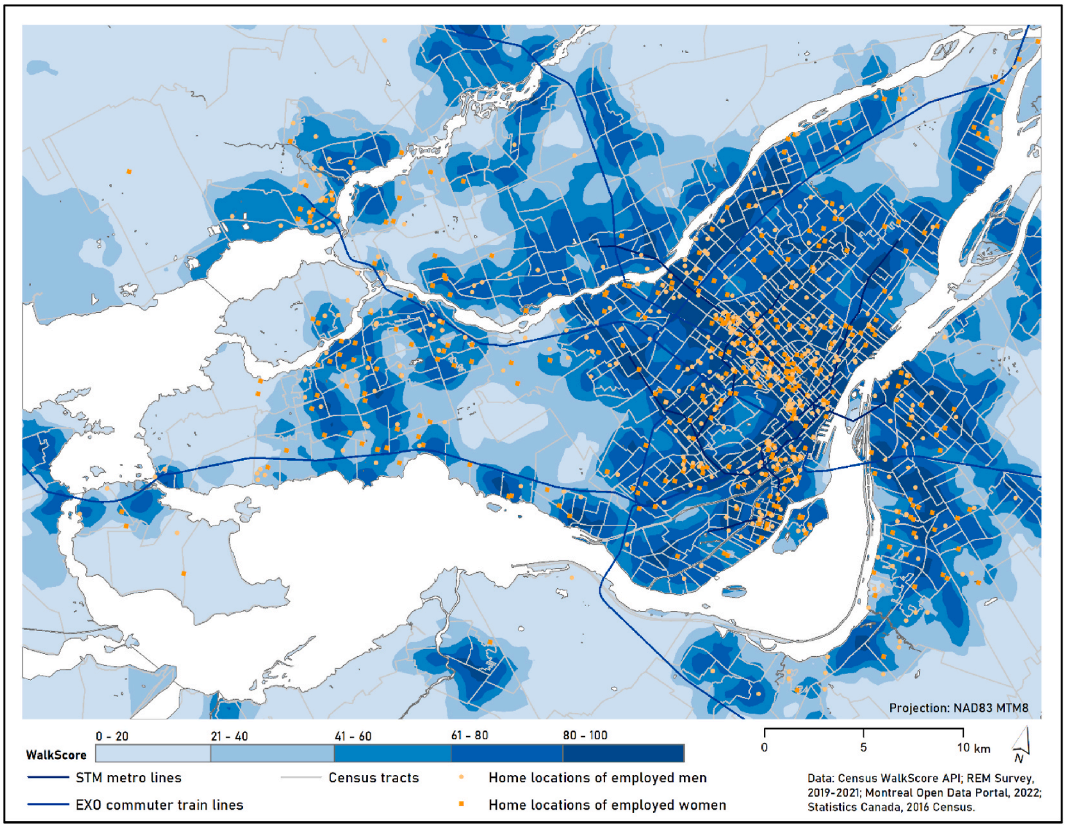

Fig. 2. Context map of study area: neighborhood WalkScore© and home location of survey respondents.

and 65% for men in 2021, during the COVID-19 pandemic. In terms of traditional commutes, in year 2019 women and men most frequently commuted via public transit at 48% and 41%, respectively. In 2019, they were similarly likely to use a car (29% for women, 31% for men), yet men were more likely to use active travel (17%) than women (13%). In 2021, during COVID-19, both women and men considerably reduced their use of public transit, to 16% and 17% respectively. In comparison, the percentage of women and men using car or active travel to commute remained similar to pre-pandemic levels.

4.2. Modelling results

The results for both sets of models for women and men, which will be presented in this section, are exhibited in Table 2. Mainly, this table presents the effect of our set of independent variables on the dependent variable: the individual's BMI. Additionally, Table 2 presents the random effects of each model which reflect the multilevel structure of the data, and which will also be discussed in this section.

According to the first set of models, when keeping all other variables constant, women's BMI increased by 0.62 kg/m^2 (95% C.I. = 0.21–1.02) between 2019 and 2021. This is in contrast with men, for which no significant change in BMI was observed.

Modelling results show that BMI increases non-linearly with increasing age. Women in the 35–54 years age range have a BMI of 2.12 kg/m^2 (95% C.I. = 0.33–3.92) higher compared to women in the youngest age group of 19–34. Women of 55 or more years of age have a BMI of 2.66 kg/m^2 (95% C.I. = 0.20–5.11) compared to women in the youngest age group, representing a comparatively small increase compared to women 35–54 years of age. Similar results are observed for men, where the 35 to 54 age group have a BMI of 3.28 kg/m^2 (95% C.I. = 1.93–4.63) higher compared to the youngest men group. Men of 55 or more years of age have a BMI of 3.27 kg/m^2 (95% C.I. = 1.58–4.96) higher than the youngest men group, which represents no significant change compared to men in the 35 to 54 age group.

Recreational physical activity showed to decrease BMI significantly only among men by −0.21 kg/m^2 (95% C.I. = −0.42 to −0.01). While there is no statistically significant difference in BMI between immigrant and non-immigrant women, men born in Canada have a BMI of 1.34 kg/m^2 (95% C.I. = 0.23–2.46) higher than immigrant men. Women that reported to have a disability which affects their transport needs have an increase in BMI of 1.49 kg/m^2 (95% C.I. = 0.03–2.95), whereas men with disabilities show no significant increase in BMI. Furthermore, having a positive life satisfaction of general health was negatively associated with BMI, at −0.28 kg/m^2 (95% C.I. = −0.44 to −0.11) for women and −0.61 kg/m^2 (95% C.I. = −0.81 to −0.42) for men.

Table 2
Body Mass Index associated with neighborhood walkability and commute, estimated through random-coefficient models: REM survey, Montréal, Canada, 2019–2021.

Variable	Model 1				Model 2			
	Women		Men		Women		Men	
	Coefficient	95% CI	Coefficient	95% CI	Coefficient	95% CI	Coefficient	95% CI
(Intercept)	26.31***	23.71–28.91	28.93***	26.50–31.37	25.64***	23.02–28.26	28.94***	26.50–31.39
Wave 2 (Year, 2021)	0.62**	0.21–1.02	−0.38	−0.86–0.09	0.37*	0.03–0.70	−0.19	−0.59–0.21
Age in 2019 (Ref. category: [19–34])								
35–54 years of age	2.12*	0.33–3.92	3.28***	1.93–4.63	2.05*	0.23–3.86	3.32***	1.98–4.67
55 or more years of age	2.66*	0.20–5.11	3.27***	1.58–4.96	2.55*	0.08–5.03	3.27***	1.59–4.96
Physical activity								
Weekly days of vigorous sports	−0.04	−0.22–0.14	−0.21*	−0.42–−0.01	−0.03	−0.21–0.15	−0.22*	−0.42–−0.02
Non-immigrants	0.83	−0.96–2.63	1.34*	0.23–2.46	0.92	−0.89–2.74	1.29*	0.17–2.40
Transportation disability	1.49*	0.03–2.95	0.59	−1.05–2.24	1.43	−0.04–2.89	0.40	−1.26–2.06
Income bracket								
30,001–60,000	0.37	−0.80–1.54	0.46	−0.89–1.81	0.65	−0.53–1.84	0.59	−0.78–1.96
60,001–90,000	0.58	−0.69–1.84	−0.04	−1.44–1.37	0.97	−0.27–2.22	0.14	−1.29–1.58
90,001–120,000	0.15	−1.12–1.42	1.27	−0.24–2.78	0.46	−0.81–1.72	1.46	−0.07–2.99
120,001–150,000	0.33	−1.11–1.77	0.84	−0.81–2.50	0.63	−0.80–2.06	1.04	−0.63–2.71
150,001+	−0.32	−1.75–1.10	0.32	−1.32–1.96	−0.15	−1.57–1.27	0.53	−1.13–2.19
Life satisfaction								
Of general health	−0.28**	−0.44–−0.11	−0.61***	−0.81–−0.42	−0.23**	−0.40–−0.06	−0.63***	−0.82–−0.43
WalkScore© quartile								
Quartile 2 (scores 40–55)	0.03	−0.95–1.02	−2.10***	−3.24–−0.96	−0.12	−1.10–0.86	−2.05***	−3.20–−0.90
Quartile 3 (scores 56–69)	0.33	−0.82–1.48	−2.17**	−3.43–−0.92	0.29	−0.86–1.44	−2.13***	−3.39–−0.87
Quartile 4 (scores 70–100)	−0.94	−2.02–0.14	−1.45*	−2.58–−0.32	−0.97	−2.05–0.12	−1.41**	−2.54–−0.27
Commuting mode								
Weekly days telecommuted	−0.16*	−0.29–−0.03	0.11	−0.05–0.26				
Telecommutes replacing car					−0.45**	−0.88–−0.02	0.09	−0.22–0.39
Telecommutes replacing active					−0.17	−0.51–0.17	−0.19	−0.56–0.17
Telecommutes replacing transit					0.16	−0.11–0.43	−0.06	−0.37–0.25
Random Effects								
σ^2 (within variance)	2.12		3.54		2.10		3.60	
$\tau_{00\ \mathrm{Individuals}}$ (between variance)	32.25		16.52		32.84		16.37	
Inter-class correlation	0.94		0.82		0.94		0.82	
$N_{\mathrm{Individuals}}$	196		262		196		262	
Observations	392		524		392		524	
Marginal R^2/Conditional R^2	0.072/0.943		0.224/0.863		0.068/0.944		0.226/0.860	

Note. 2 CI = Confidence Interval, *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

In terms of the independent variables of focus in this study, telecommuting frequency and local accessibility, our first set of models shows differing results by gender. First, in terms of telecommuting, women had a reduction in BMI of 0.16 kg/m^2 (95% C.I. = −0.29 to −0.03) for each additional weekly telecommuting day. In contrast, there was no statistically significant effect of telecommuting frequency on men's BMI. Local accessibility showed no statistically significant effect on women's BMI. However, for men, each WalkScore© quartile higher than the base group of scores 0–39, BMI decreased by 1.45–2.17 kg/m^2, all of which were statistically significant at a 95% confidence level, while keeping all other variables constant at their mean.

Our second set of models (Model 2) inquires deeper into the effect of telecommuting frequency on BMI levels, depending on the commuting mode that was replaced by working remotely. While all other variables in the model present nearly identical effects on BMI, segregating telecommuting by replaced mode presents interesting insights. For women, we can corroborate that telecommuting only has an effect of decreasing BMI when it is replacing commuting by private vehicle, with a decrease of 0.45 kg/m^2 (95% C.I. = −0.88 to −0.02) for each additional weekly telecommuting day. However, when telecommuting replaces women's commute by transit or active modes there is no statistically significant effect on BMI. For men, telecommuting has no statistically significant effect on BMI regardless of the commuting mode being replaced.

In the random effects' results, both set of models show that the between-level variance is considerably higher than the within-level variance for both women and men. This means that most variability in BMI occurs at the person level rather than between waves, which is expected given that one person's BMI in wave 2 of the survey is strongly dependent on the same person's BMI in the first wave, especially since we are considering at a gap of only two years.

5. Discussion

Our models inquire into the effects of changing commuting and telecommuting patterns on workers' BMI during the COVID-19 pandemic. While previous studies conducted during the COVID-19 pandemic have concluded that telecommuting may result in workers adopting worse dietary habits (Kubo et al., 2021) and reducing physical activity (Kooshari et al., 2021), our results show that the increase in telecommuting has not resulted in a statistically significant increase in workers' BMI. While our results show that women's BMI had a significant increase during the pandemic, we found that this increase is not explained in terms of changing commuting patterns. Furthermore, increase in telecommuting during the pandemic has resulted in a decrease in BMI for women who were previously commuting by car which is likely attributable to decreased sedentary time spent during commutes (Dons et al., 2018; Tajalli and Hajbabaie, 2017). Reducing motor vehicle usage has previously been linked to reductions in BMI, but in relation to changing to active travel or public transit (Kubo et al., 2021; Tajalli and Hajbabaie, 2017). As such, even though this finding could suggest that telecommuting is beneficial to women's physical health, further research is needed, particularly to explain the differential results between women and men.

When looking at telecommuting replacing active or public transit commutes, telecommuting did not affect women's nor men's BMI. Thus, our results emphasise the relevance of encouraging telecommuting (Chakrabarti, 2018), public transport (Noorbhai, 2022; Wasfi et al., 2013), or active travel (de Haas et al., 2021; Kitchen et al., 2011; Lee and Buchner, 2008; Saunders et al., 2013) use over car commutes for public health reasons as previous works have (Tajalli and Hajbabaie, 2017). These findings are relevant for policy recommendations since flexibility in telecommuting could contribute to public health benefits. This can be implemented by providing information to telecommuters about safe and healthy workplace practices, outlining telecommuting practices for companies and their benefits, and the implementation of formal policies on telecommuting guidelines.

The gendered findings between local accessibility as measured by WalkScore© and BMI are coherent with previous research (Ross et al., 2007; Wasfi et al., 2016b). The built environment has been shown to have differential impacts between women and men, with urban sprawl and walkability having a statistically significant effect only on men (Kelley et al., 2016; Ross et al., 2007; Wasfi et al., 2016b). The relationship between local accessibility and BMI relates to the increased potential to complete trips by active modes to access amentities, therefore increasing physical activity and decreasing one's BMI (de Haas et al., 2021; Kitchen et al., 2011; Saunders et al., 2013; Tarlov et al., 2020; Veisten et al., 2011; Wasfi et al., 2016a, 2017). However, WalkScore© focuses solely on accessibility to local amenities, thus ignoring a plurality of other attributes that contribute to the walkability, such as perception, aesthetics, and safety (Hajna et al., 2013; Herrmann et al., 2017; Rodrigue et al., 2022). While higher walkability levels have been shown to beget positive health outcomes in the population (Hajna et al., 2015; Lee and Buchner, 2008), our results suggest that if only the local-accessibility component of walkability is addressed, then the outcome may only be positive for men. This is coherent with past research that has highlighted the higher attention given by women to safety considerations and micro-scale features of the built environment (Clifton and Livi, 2005; Jensen et al., 2017).

Other gendered findings included the fact that women with physical disabilities had higher BMIs. This is relevant as disabilities and obesity can have a compounding effect on health outcomes (Armour et al., 2013; Ferraro et al., 2002). This illustrates that integration of universal accessibility measures is key for built-environment policies to effectively address gender inequities in urban environments. Improvements in neighborhood safety, the micro-scale built environment, and universal accessibility could therefore go a long way to sustain better health outcomes in women, especially those with disabilities that impact their travel.

In both sets of models, when assuming that all considered independent variables remain constant, only women reveal a statistically significant increase in BMI between the first wave (pre-covid) and the second-wave (during covid). Additionally, the marginal R^2 of both models for women is lower than men's. These findings suggest that, even though the rational for separating women and men when analyzing BMI is biological, and thus sex-based (Campbell, 2016; Wisniewski and Chernausek, 2009), gendered processes (i.e. based on the different social roles and norms between genders) in relation to travel behvaior and the effects of the COVID-19 pandemic are also present. While biological differences between women and men explain how a similar behavior or exposure can lead to differential health outcomes, gender-based processes (i.e. social norms and social roles) might dictate whether an individual is brought to engage in a certain behavior in the first place. These findings are also coherent with past research that has highlighted gendered differences in attitudes towards weight, phsyical activity and nutrition (Tsai et al., 2016) as well as differential effects of social cohesion on BMI between women and men (Guilcher et al., 2017). To this literature, we add that women and men's BMI is influenced differently by travel behavior, in this case telecommuting, and the home built environment.

We also highlight that the COVID-19 pandemic has disproportionally affected the BMI of women which is in line with a previous study (Flanagan et al., 2021) but contradcits another one (Akter et al., 2022). This finding adds to previous studies that have shown worse mental health outcomes for women during the COVID-19 pandemic (Vindegaard and Benros, 2020; Xiong et al., 2020). Such disproportionate distribution of adverse health ouctomes during the COVID-19 pandemic has been discussed as likely stemming from on-going gendered economic and social inequities (Fortier, 2020), as well as increased in care-giving tasks for women (Collins et al., 2021; Power, 2020). The disproportionate burden of care-tasks has also been increasingly discussed in the travel behavior literature as a primary barrier to women conducting active travel, thus providing a potential pathway to explain differential health outcomes (Craig and van Tienoven, 2019; Grant-Smith et al., 2017; Ravensbergen et al., 2022a).

The results presented in this study on the diverse factors affecting changes in men's and women's BMI represent a relevant contribution to the literature in several ways. First, through our case study in the city of Montréal, Canada we illustrate how COVID-19, particularly through changes in commuting patterns, has affected workers' BMI. Not only are these results, to our knowledge, the first to link BMI and COVID-related telecommuting, but they do so through a panel design which is better suited to study changes in behaviors and their outcomes (van de Coevering et al., 2015). Although these results may be highly context specific and further research is needed to corroborate them, we speculate that similar trends could be expected in other large North American cities. To corroborate this, the results obtained in this study may be replicated in different contexts through the application of a multi-period survey to the same group of participants.

6. Conclusion

In this paper, we analyzed the factors affecting BMI of employed women and men during the COVID-19 pandemic, with a focus on changing commuting and telecommuting patterns, as well as on local accessibility levels around the household. By utilizing a set of two weighted multi-level linear regressions, we analyzed a survey administered in two waves, in the years 2019 and 2021, within the Montréal CMA. Through our models, we find gendered effects of telecommuting on BMI, with increases in telecommuting resulting in decreases in BMI only for women for whom telecommuting replaced commutes previously done by car. Further gendered findings are observed in terms of the effect of local accessibility by walking on BMI and overall changes in BMI during the pandemic. Overall, these gendered realities highlight limitations with commonly used measures to correctly capture factors influencing women's health outcomes as it relates to travel behavior. It also highlights the need to not only consider sex-based (biological) differences in processes influencing health outcomes, but also gender-based ones that might provide much-needed context to understand health inequities.

While BMI has been used as a measure of physical health in this study, we acknowledge its limitations as presented in previous research (Buss, 2014; Gutin, 2018; Lopez-Jimenez and Miranda, 2010; Nuttall, 2015; Romero-Corral et al., 2008). Height, fat distribution, and muscle are not considered in using BMI as a diagnostic tool (Lopez-Jimenez and Miranda, 2010). This is shown in our models, as vigorous physical activity for women was not necessarily associated with a lower BMI, but is a core proponent of one's health. Yet, BMI is predictive of body fat content, adverse health outcomes, and general health (Gutin, 2018). BMI allows us to understand the physical health effects of several factors on the respondents, but further research could include additional components of physical health.

Additional limitations can be mentioned with regard to the longitudinal apporach we have taken. First, the magnitude of fixed effects in the models are assumed to be equal in both waves of the survey, which is not necessarily the case due to the rapidly changing context of the pandemic. Second, while both survey waves were applied during the fall season, this only partially controls for seasonal effects. This survey design allows us to assume that any observed differences in travel or physical activity patterns are not attributable to seasonal effects. However, further studies are needed to explore seasonal variations in these patterns, as well as in BMI, after the pandemic.

By providing a better understanding of the impacts of telecommuting and local accessibility on workers' health using a longitudinal data analysis approach, we hope to inform public policymaking that effectively addresses current health issues. More specifically, our results show that, if high levels of telecommuting are meant to be sustained in the future, more attention needs to be directed to workers' commute transport mode being replaced as well as to gendered externalities of telecommuting. Additionally, our results illustrate the relevance of improving walkability around homes to promote active mobility, especially for men. However, we have also shown that only focusing on the local-accessibility component of walkability could lead to increasing the gap in active mobility between women and men. Thorough considerations of gendered interactions with the built environment are therefore needed to equitably promote more active travel and healthier lifestyles.

7. Future work

Future studies can complement this work's analysis and results in several ways. First, future works may replicate this study on a different setting, such as a different city in North America or another context. This could either corroborate the links between changes in BMI and COVID-related telecommuting or show insights into the local factors that may give rise to differences in these links. Other further studies, although harder to replicate, could consider more integral measures of general health rather than using the BMI. This could include not only further details into respondents' body composition, such as fat and muscle distribution (Lopez-Jimenez and Miranda, 2010), but also other health related indicators such as stress levels.

Future research can further our results by incorporating factors not considered in our models which could have contributed to the explanation of BMI changes during the pandemic including the differential results observed between women and men. This may include smoking habits, eating habits, and sedentary time which have all been shown to influence BMI and overall health (Kubo et al., 2021). Changes in nutrition and lifestyles (Akter et al., 2022; Robinson et al., 2021), and increasing work-life conflicts during the pandemic (Flanagan et al., 2021) could have further impacted BMI of study participants. These factors, along with those previously mentioned that have been shown to contribute to gendered health outcomes, should all be considered in future research on the impacts of telecommuting and local accessibility on BMI. Additional research, likely qualitative, should also be conducted to unearth other factors that influence BMI differently since the COVID-19 pandemic as well as factors that disproportionally affect women's BMI.

Finally, further studies could inquire into the differing post-pandemic effect of commuting mode, telecommuting, and the built environment on BMI when compared to pre-pandemic relationships. Whereas our study assumes that each independent effect, such as that of telecommuting, was the same pre-pandemic as it was during COVID-19, future studies could test a different hypothesis. That is, verifying if the direction and magnitude of these effects is radically different due to the COVID-19 pandemic.

Author statement

The authors confirm contribution to the paper as follows: Study conception and design: Commers, Victoriano-Habit, Rodrigue, El-Geneidy; Data collection: Victoriano-Habit, Rodrigue, Kestens, El-Geneidy; Analysis and interpretation of results: Commers, Victoriano-Habit, Rodrigue, Kestens, El-Geneidy; Draft manuscript preparation, Commers, Victoriano-Habit, Rodrigue, Kestens, El-Geneidy. All authors reviewed the results and approved the final version of the manuscript.

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