Analyzing the mediating effect of individuals' identities on the interaction between walkability indices and walking behaviors

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ABSTRACT

Walkability measures are generated by public health and transport professionals for different purposes. While there is a plethora of walkability measures in the literature, comparisons between these measures and their capabilities in contextualizing the walking behavior among different individual identities compared to expected behaviour are scarce. Using trip data from the 2018 Origin-Destination survey in Montréal, Canada, this paper evaluates the interactions between two commonly used walkability indices – Walkscore© and the MAPS-Mini audit tool – and socio-demographic characteristics to evaluate how well these indices help explain the expected differences in walking behaviours between social groups. Weighted binary regressions are used to model the probability of adults walking to destinations as a function of trip, person, household, and walkability characteristics. Sensitivity analyses are conducted for 4 variables – gender, age, median household income, and number of children in the household – based on interactions with each of the walkability indices. Results show that the MAPS-Mini audit tool is better at explaining differences in walking behaviours across genders and ages while Walkscore© is more coherent in explaining differences between income groups. Both indices explain similarly the effect of children on adults' walking behaviour. This research can be of interest to transport and public health professionals as they work towards generating equitable walkable environments, as the research provides an assessment of the two commonly used walkability indices and their capabilities in explaining differences in walking behaviour for different socioeconomic group.

Keywords: Walkability, Walking, Walkscore, Audit, Built Environment

1. INTRODUCTION

The concept of walkability encompasses a wide range of attributes of the natural, built, and social environments. The way researchers and policy makers conceive of this concept reflects different preoccupations and policy goals (*1; 2*). Broadly speaking, walkability – as the subcomponent of Active Living Environments (ALEs) focusing on walking (*3*) – can be separated into two primary goals: promoting increased walking rates and/or promoting improved walking experience. Choosing between one or the other or both as goals of walking interventions can influence the areas and population impacted by them (*4*). Past research has shown that walking behaviours vary with gender (*5-8*), age (*9-12*), income (*4; 13*) and multiple other demographic and socio-economic factors. These differences have been linked to the mediating effect of one's identity on their interaction with the built and social environment (*4-6; 14*). This mediating effect has been conceptualized as the subjective nature of walking (*15-17*). Promoting increased walking rates in social groups that are mostly left out by the current approach should therefore be a priority. Unfortunately, focusing solely on improving walking rates – as is often the case with a majority of "walkability" indices – tends to lead to oversight of subjective differences between social groups potentially leading to widening inequities (*2; 4; 6; 18*). Contrastingly, past research has highlighted that interventions targeted at the micro-scale environment – which more directly impacts the walking experience – can help reduced observed inequities in walking behavior (*6; 7; 19*).

To contrast these different but not mutually exclusive goals of walkability interventions, we will focus on comparing two commonly used measures of walkability in the transport and public health fields. On one hand, we will consider local-accessibility as measured by Walkscore© – a composite index reflecting block length, intersection density and gravity-based accessibility to a fix set of destination (*18*) – which is primarily oriented towards increasing walking rates and commonly used by transport professionals. On the other hand, we will be adding the micro-scale built environments as quantified through the MAPS-Mini Audit tool – a validated street level audit tool commonly used by public health professionals – which describes features that pedestrians directly interact with while walking and therefore can be understood as reflecting intents to improve walking rates and walking experience (*20; 21*). Our analysis will focus on contrasting the explanatory power of each of these walkability indices to explain observed walking behaviors differences across socio-demographic and socio-economic characteristics. Through this study we aim to emphasize the need for a shift away from walkability interventions as solely based on promoting purposive walking rates towards walkability as a multi-scalar, inherently subjective concept that is intrinsically dependent on individuals' identities.

2. LITERATURE REVIEW

Walkability research has been and continues to be animated by debates surrounding the exact definition of the concept of "walkability" and what goals it should represent (*1; 3*). While a sizable part of the scholarship has been dedicated to meso-scale proxies aimed to understand determinants of walking rates – such as Walkscore© –, these metrics have shown to be limited in their ability to accurately predict walking rates (*2; 15; 17; 18; 22*) or to capture the subjective experience of walking (*15-17*). These findings are even more relevant when differentiating between purposive (i.e. utilitarian) and discursive (i.e. leisure) walking (*11; 23*).

A first path explaining these issues has been the lack of consideration of street micro-scale characteristics in these metrics (*22*). Such elements of the built-environment have been shown to impact pedestrian behaviour both in term of walking rates but also primarily through their walking experience (*6; 7; 19*). These data are usually collected through built environment audits with the most popular tools used being the Irvine Minnesota Inventory (*24; 25*) and the MAPS audit tool (*20; 21*). Still, even these tools present limitations in accurately capturing walking rates, once again more so for leisure walking (*20; 25*).

As such, to better understand the variability in walkability tools' ability to predict walking rates, characteristics of the pedestrians must also be considered in addition to those of the built environment. Such characteristics have rarely been considered in past research using Walkscore© and when they were, it was mostly as controlling variable and not as potential mediating factors of the built environment on walking behaviors (*18*). People with lower incomes have been shown to be more likely to walk in areas with low Walkscore© values (*4*) while also experiencing a weaker effect of local accessibility on their walking behavior (*13*). Past research has also highlighted how high-income areas benefit from higher quality streetscapes than low-income areas at equal Walkscore© values (*26*) and how high-level of physical walkability are associated with heightened socio-economic distress in local residents (*16*).

In term of gendered differences, past studies have shown mixed effects of Walkscore© on women's walking rates (*5; 27*) while improvements in the micro-scale built environment have been linked to increased walking rates (*7*). These effects can be attributed to women being more likely to allocate more importance towards perceived safety – both in term of crime and traffic – in their decision to walk or not (*6; 8*). This gendered reality has been partially attributed to women being more socially conditioned to be risk-averse than men (*28*). Gendered distribution of mobilities of care have also been highlighted as limiting factors to women's mobility options, impacting primarily their ability to use active transport (*29-31*).

In term of age, older adults have been associated with higher risk of fatality in car-pedestrian collisions due to their increased vulnerability (*32*). Consequently, past research has highlighted lower walking rates for older adults (*9-12*) with differential impacts of the built environment being observed between age groups (*12; 14*). Fear of falling (*33*), avoidance of risky or uncomfortable environments (*34*) as well as extreme urban density and land-use mix (*35*) have all been negatively associated with older adults' walking behaviors while micro-scale features such as tree cover and sidewalk conditions have been positively linked to walking behavior for this demographic (*19*).

Lastly, many studies have highlighted how the primary limiting factors that dictate active transport behavior in children and subsequently other household members, are parents' fears and concerns, not walkability (*36-41*). Perceptions that driving is more convenient and essential when travelling with children has been highlighted as common amongst parents (*42; 43*) leading to the presence of children in the household being correlated with car ownership, a factor that has been shown to have a negative effect on active transport behavior (*9; 41*).

Given the limited consideration of socio-demographic and socio-economic conditions of pedestrians as mediating factors, this paper aims to contribute to the existing literature by identifying differences between social groups in the impact of the built environment on walking behavior. Additionally, using both a local accessibility proxy – Walkscore© – and a micro-scale tool – the MAPS-Mini audit tool – we aim to further identify which measure of walkability best explain the observed and theoretically supported differences in walking behavior between social groups. Doing so will be of value to researchers and transport and public health practitioners as they aim to use the right tool to identify areas of interventions that could result in the decrease of inequities in walking rates.

3. METHODOLOGY

3.1 Data

The study area used for this paper was dictated by the availability of data collected using the MAPS-Mini audit tool, which is a street-level built-environment audit that has been validated in previous research (*20; 21*). Data was collected as part of a built environment audit conducted in a 1km service area around the stations of the upcoming Reseau Express Metropolitan (REM) a new light-rail train (LRT) system in Montreal, Canada (Figure 1). In total, 2,497 street segments were audited using an adapted version of the MAPS-mini audit tool. Data collection took place between May 25^{th} to July 1^{st} 2021 and May 5^{th} and June 10^{th} 2022 and required a total of 650 hours from 18 auditors who were all trained prior to the audit on the collection of the objective data.

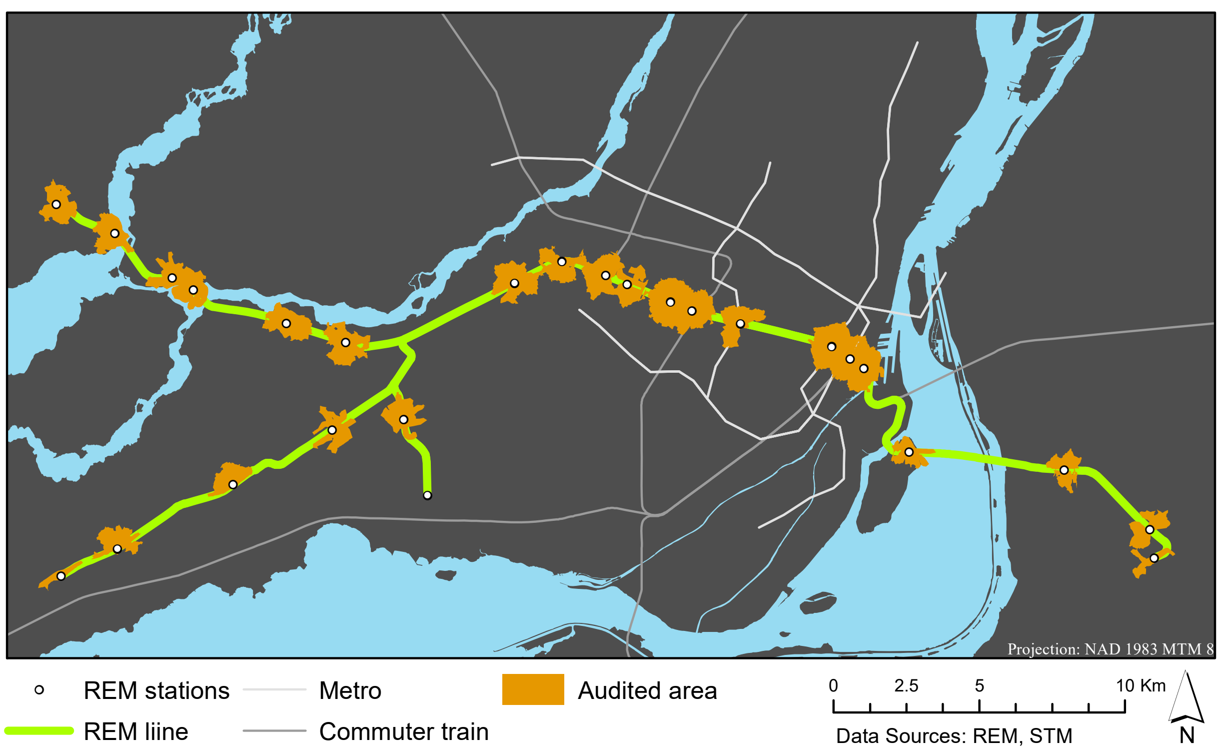

Figure 1 One kilometer service areas audited around the new REM in Montréal, Canada

Trip based data was collected from the 2018 Montréal Origin-Destination (O-D) survey which is conducted every five years by the regional public-transit planning agency in the Montréal metropolitan region. The O-D survey collects a travel diary record covering all household members trips on the previous day for a random sample of 5% of the households in the Montréal area. Expansion factors are then derived for each trips, person, and household to allow for representative analyses.

Trips from the O-D survey were filtered to get to the final sample. Out of all the trips recorded in the O-D survey (n=393,826) all those conducted by modes other than walking, cycling, public transit, or car – driver or passenger – (n=16,910) were removed. Then only trips from households falling within the 1-kilometer service areas around the REM stations (Figure 1) were selected (n=9,769). For each variable of interest obtained from the O-D survey (Table 1), trips that did not report a usable answer (n = 2,396) were removed from the sample. Additionally, children below 18 (n=801) were also removed as factors influencing their propensity to walk have been shown to differ from adults (*37; 39*) which could affect the relationship between age and the built environment. A trip chaining dummy variable was then derived based on whether the trip in question was part of a succession of trips starting each from the end location of the previous one. From there, trips were then filtered to keep only those that started at the home location (n=2,964). Lastly, one trip was randomly selected for each person to avoid having them appear more than once in the sample leading to a final sample of 2,352 trips.

Using the final sample of trips, each household's MAPS-mini audit score was calculated using all audited streets reachable in a 400-meter network distance from the home location. If the 400-meter service area for a household intersected with areas for which data was not collected, it was assumed that the audited streets were representative of the neighboring built environment. The MAPS-Mini audit score – a score between 0 and 21 – was then weighted based on the total length of each street segments and averaged. Values were subsequently normalized using the maximum value in the sample to correct the left-sided skewness of the data. For Walkscore©, values at the household location were collected through the online API. Both MAPS-Mini and Walkscore© values were converted to be on a scale from 1 to 10 scale to favorize comparison. Walking travel times were also calculated for each O-D pair – no matter what mode was actually used for the trip – along the street network, obtained from open street maps, using the routing package r5r (*44*) in R with a walking speed of 4.5 kilometer/hour (*45*). Trip purpose data from the O-D was aggregated as being either work, school, shopping or other. Household level characteristics considered included household size, the number of cars accessible, as well as the presence and number of children in the household. Median household income which was reported in $30,000 increments in the O-D survey was also used, but for the purpose of the linear models, it was combined into five classes. Complete descriptive statistics of the sample are displayed in Table 1.

Table 1 Descriptive statistics of model variables

Variables	**Mean**	**St. Dev.**	**Min**	**Max**
Dependent variable				
Walking trips	0.142	0.329	0.00	1.00
Independent variables				
Trip-level characteristics				

Trip Purpose				
Work	0.492	0.495	0.00	1.00
School	0.099	0.281	0.00	1.00
Shopping	0.120	0.306	0.00	1.00
Other	0.289	0.434	0.00	1.00
Walking travel time [Minutes]	90.930	72.643	3.00	200.00
Trip chaining [Binary]	0.195	0.376	0.00	1.00
Person-level characteristics				
Gender [Women]	0.503	0.496	0.00	1.00
Age [Years]	48.960	23.276	18.00	96.00
Household-level characteristics				
Household size [Count]	2.650	1.480	1.00	7.00
Household cars [Count]	1.407	0.979	0.00	6.00
Presence of children under 13 [Binary]	0.207	0.384	0.00	1.00
Household Median Income				
$0 - $30,000	0.125	0.312	0.00	1.00
$30,000-$60,000	0.213	0.389	0.00	1.00
$60,000-$90,000	0.187	0.369	0.00	1.00
$90,000-$150,000	0.244	0.409	0.00	1.00
$150,000 +	0.232	0.402	0.00	1.00
Walkability indices				
Walkscore [Normalized]	5.823	2.907	0.20	10.00
MAPS Mini Score [Normalized]	3.642	1.538	0.00	6.82

It should be noted that the O-D survey has been recording sex, not gender, since it first inception in the 1970s. However, the primary pathways explored to explain the observed difference between women and men in travel behaviors are mostly structured around the social construct of gender and not biological sex differences (*6; 8; 28; 31*). As such, while the available data only records sex, since 99.67% of the Canadian population is identifying as cis-gendered (*46*), a generalizable trend can be inferred by assuming gender is concordant to declared sex for the analysis. The implications and limitations of such assumption will be discussed at the end of the paper. Lastly, while age and walking travel times are reported in years and minutes respectively in Table 1, they where both divided by 10 in the statistical regression models resulting in coefficient reported being for marginal increases of 10 years in age and 10 minutes in walking travel times.

3.2 Analysis

Using the trip expansion factors from the O-D survey, weighted binary logit models were used to model the probabilities of having taken a homebased trip by walking. It was decided to use a single-level model given the goal of the analysis to assess the influence of individual, household and built environment characteristics on walking propensity, which is not possible when observations are nested within individuals or households (*4*). In order to evaluate the differential effect of local accessibility and the micro-scale built environment across person and household level characteristics, interactions variables were modelled between the characteristics of interest and the walkability indices used – Walkscore and the MAPS-Mini audit tool. Each interaction was inputted into a separate model using the same set of control variables present in the original models. For each interaction variables, a sensitivity analysis was generated by sensitizing the variable itself, the interacting-walkability variable and the interaction itself. All other independent variables were fixed at their mean except for walking travel time which was fixed at 15 minutes to reflect a more realistic walking trip than the average (90.93 minutes). Walking rates were then calculated and graphed for each interaction variables.

4. RESULTS

Results from the base linear logit model (Table 1) reveal that all predictors included had a a statistically significant effect at the 5% level on the probability of taking a homebased trip by walking and that the directionality of these effects was the same between both models regardless of the walkability index used. Walkscore allowed for a slightly better fitter model (R^2 = 0.480) than the MAPS-Mini audit tool (R^2=0.464), but the difference is small.

Table 2 Odds ratios from binary logit models predicting the probability of taking a trip by walking

Predictors	**Base models**		**Gender Interaction**		**Age interactions**		**Income interactions**		**Children interactions**	
	Walkscore	*MAPS-Mini*	*Walkscore*	*MAPS-Mini*	*Walkscore*	*MAPS-Mini*	*Walkscore*	*MAPS-Mini*	*Walkscore*	*MAPS-Mini*
(Intercept)	4.15***	18.01***	4.51***	33.46***	7.47***	83.52***	5.35***	12.22***	3.53***	14.53*
Trip-level characteristics										
Trip Purpose [Reference: Other]										
Work	1.51***	1.66***	1.52***	1.65***	1.51***	1.64***	1.54***	1.73***	1.53***	1.67**
School	0.84**	0.80***	0.84**	0.79***	0.83***	0.82***	0.81***	0.77***	0.85**	0.80**
Shopping	0.89*	0.90*	0.89*	0.88*	0.89*	0.89*	0.88**	0.90*	0.90*	0.90*
Walking travel time	0.43***	0.41***	0.43***	0.41***	0.43***	0.41***	0.43***	0.41***	0.43***	0.41**
Trip chaining	0.48***	0.46***	0.48***	0.46***	0.48***	0.46***	0.48***	0.47***	0.48***	0.46**
Person-level characteristics										
Gender	0.84***	0.81***	0.72**	0.23***	0.84***	0.80***	0.84***	0.80***	0.84***	0.81**
Age	0.81***	0.77***	0.81***	0.77***	0.71***	0.55***	0.81***	0.78***	0.82***	0.78**
Household-level characteristics										
Household size	0.95**	0.87***	0.95**	0.87***	0.94**	0.86***	0.95**	0.86***	0.97	0.88**
Household cars	0.58***	0.54***	0.58***	0.54***	0.58***	0.54***	0.59***	0.55***	0.57***	0.53**
Presence of children under 13	0.62***	0.59***	0.62***	0.58***	0.61***	0.59***	0.64***	0.60***		
Number of children under 13									0.90	1.06
Median Household income [Continuous]							0.97	1.24***		
Median Household income [Reference: - $30,000]										
$30,000-$60,000	1.23***	1.23***	1.23***	1.23***	1.23***	1.25***			1.22***	1.22**
$60,000-$90,000	1.25***	1.35***	1.26***	1.33***	1.25***	1.35***			1.24***	1.34**
$90,000-$150,000	1.71***	1.95***	1.71***	1.95***	1.68***	1.90***			1.67***	1.88**
$150,000 +	1.38***	1.57***	1.39***	1.55***	1.36***	1.55***			1.35***	1.52**
Walkscore	1.23***		1.21***		1.14***		1.19***		1.24***	
MAPS Mini Score		1.09***		0.99		0.85***		1.17***		1.12**
Interactions										
Gender * Walkscore			1.02							

Gender * MAPS-Mini Score				1.23***						
Age * Walkscore					1.02***					
Age * MAPS-Mini-Score						1.06***				
Income * Walkscore							1.01**			
Income * MAPS-Mini Score								0.98***		
Number of children * Walkscore									0.98*	
Number of children * MAPS-Mini Score										0.94**
R^2	0.480	0.464	0.480	0.465	0.484	0.468	0.479	0.460	0.481	0.464

Note : *** p>0.001; **p>0.01; *p>0.05

In term of trip characteristics, work trips were 51% more likely to be by walking compared to other utilitarian trips in the Walkscore model and 66% more in the MAPS-Mini model, ceteris paribus. School trips were 16% less likely to be by walking for the Walkscore model and 20% less likely in the MAPS-Mini model compared to “other” utilitarian trips, holding other things constant. Similarly, homebased shopping trips were 11% less likely to be by walking for the Walkscore© model and 20% less likely in the MAPS-Mini model when compared to the “other” utilitarian trips. Every increase in walking travel time of 10 minutes meant that a trip was less likely to be by walking by 57% for the Walkscore© model and 59% less likely in the MAPS-Mini model, holding other variables constant at their mean. Lastly, if a trip was part of a trip chain it was 52% less likely to be by walking for the Walkscore model and 54% less likely in the MAPS-Mini model, ceteris paribus.

For person level characteristics, women were 16% less likely than men to be taking a walking trip in the Walkscore model and 19% less likely in the MAPS-Mini model. Every increase of 10 years in age also led to being 19% less likely to be taking a walking trip in the Walkscore model and 23% less likely in the MAPS-Mini model.

For household characteristics, every added person led to a reduction in odds of walking of 5 % in the Walkscore model and 13% in the MAPS-Mini model. Every added car accessible in a household led to a reduction in odds of walking by 42 % in the Walkscore model and 46% in the MAPS-Mini model, ceteris paribus. The presence of children aged below 13 years old led to a reduction in odds of walking of 38 % in the Walkscore model and 41% in the MAPS-Mini model, holding other things constant. In term of median household income, all groups were more likely to walk for a homebased trip than those in the lowest income groups by 23% to 71% in the Walkscore model and by 23% to 95% in the MAPS-Mini model.

Finally, improvements of 1 in normalized Walkscore values at home location led to an increase of 23% in the probabilities of taking a homebased trip by walking while an improvement in 1 of the normalized MAPS-Mini score led to an increase of 9%, holding other things constant.

4.1 Gender

The interaction between Walkscore© and gender (OR = 1.02, 95% CI [0.99-1.05]) was not statistically significant ($p = 0.183$) meaning that Walkscore© effect on women and men is similar in our models. On the contrary, the interaction between the MAPS Mini score and gender (OR= 1.23, 95% CI [1.17-1.30]) was statistically significant ($p<0.001$) meaning that a differential effect of MAPS Mini score was observed between women and men. With every increase of 1 in the normalized MAPS-Mini score, women’s probabilities to walk increased by 23% more than men’s signifying that women are more influenced by changes in the micro-scale built environment than men. This is exemplified in Figure 2 with increases in Walkscore© behaving similarly across gender with probabilities lines never crossing while increases in the normalized MAPS-Mini score led women to eventually surpass men in predicted walking rates.

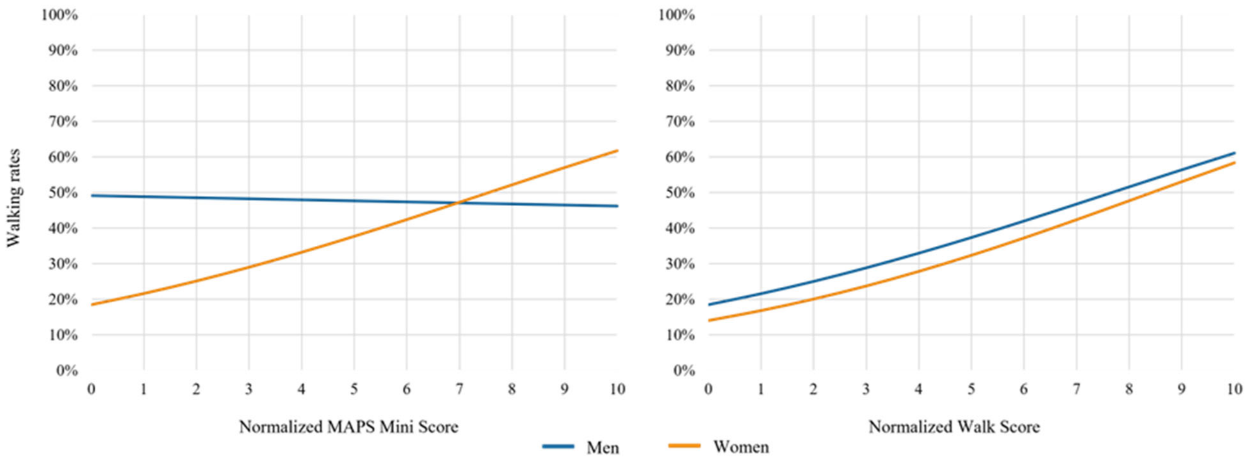

Figure 2 Walking rates prediction from interactions between gender and walkability indices

The lack of statistical significant differences in the effect of Walkscore© on gender aligns with past research looking at the correlation between this measure and physical activity (*27*) but it goes against findings on the differential impacts of local accessibility on active transport between South Asian American women and men (*5*). The findings for MAPS-mini corroborate findings from a previous study that women's walking rates increase significantly more following street-level interventions than men (*7*). This reality can be explained by the heightened considerations of safety – both in term of crime and traffic – that have been observed amongst women compared to men (*6; 8*). Indeed, women are socially conditioned to be more risk-averse than men leading to heighten avoidance in environment with low perceived safety (*28*). Interventions such as proper street lighting or safe walking infrastructures – which are both considered in the MAPS-Mini audit tool – have been shown to help tackle this issue (*6*).

4.2 Age

The interaction between age and Walkscore© (OR = 1.02, 95% CI [1.01-1.03]) was statistically significant ($p<0.001$) meaning that for every increase of 10 years in age, an improvement of 1 in normalized Walkscore© would lead to an increase in walking rates 2% larger than for someone 10 years younger, ceteris paribus. Similarly, the interaction between age and MAPS-mini (OR= 1.06, 95% CI [1.04-1.07]) was also statistically significant ($p<0.001$) meaning that for every increase of 10 years in age, an improvement of 1 in normalized MAPS Mini would lead to an increase in walking rates 6% larger than for someone 10 years younger, holding other variables at their mean. The positive significant odd ratios of these interactions therefore imply that both local accessibility and the micro-scale-built environment gain importance in promoting walking as adults age. Still, as exemplified in Figure 3, while the initial gap between age groups shrinks as Walkscore© increases, there is no convergence meaning that inequalities in walking rates between age groups remain present at "perfect" local accessibility. While this reality also holds for the normalized MAPS Mini score, the convergence is more pronounced.

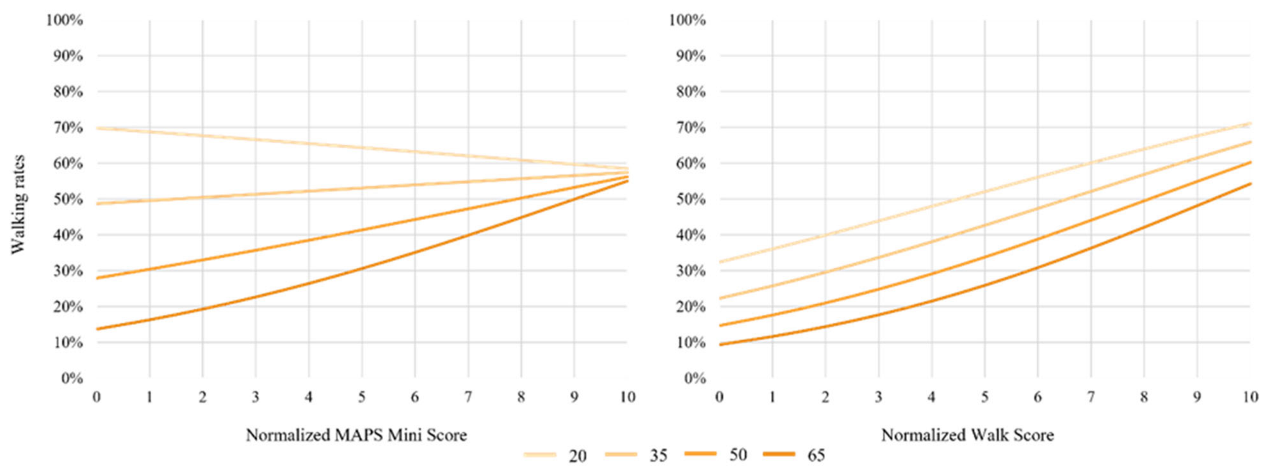

Figure 3 Walking rates prediction from interactions between age and walkability indices

The observed decrease in propensity to walk with increase in age in the logistic models is coherent with previous research (*9-12*). The positive interactions between both Walkscore© and MAPS-Mini with age are also coherent with past research that indicated that the implication of walkability varied across age groups (*12; 14*). The fact that increases in the MAPS-mini score promotes a convergence of walking probabilities across age groups indicate that the micro-scale environment might be gaining more importance through aging compared to local accessibility. Past research has highlighted the importance of micro-scale characteristics such as tree cover and sidewalk conditions for older adult's walking behavior (*19*). Given that older adults have been consistently associated with higher risk of fatality in car-pedestrian accidents due to their increased vulnerability (*32*), it makes sense that their walking behavior would be predominantly shaped by the quality of the street environment they interact with and how safe it makes them feel (*33; 34*).

4.3 Median household income

The interaction between median household income and Walkscore© (OR = 1.01, 95% CI [1.00-1.02]) was statistically significant ($p<0.008$) meaning that every increase of $30,000 in median household income will lead to an increase in walking rates 1% larger for an improvement of 10 in Walkscore©, all else equal. As such, higher income groups which start at lower walking rates in areas with poorer local accessibility will end up with the highest walking rates in higher accessibility areas (Figure 4). For MAPS-Mini, the interaction with median household income (OR= 0.98, 95% CI [0.96-0.99]) was also statistically significant ($p<0.001$) meaning that every increase in $30,000 in median household income will lead to an increase in walking rates by 2%. The negative significant odd ratio of this interaction implies that improvements in the micro-scale built environment promote walking more the lower your median household income is leading to the convergence of the predicted walking rates across income groups (Figure 4).

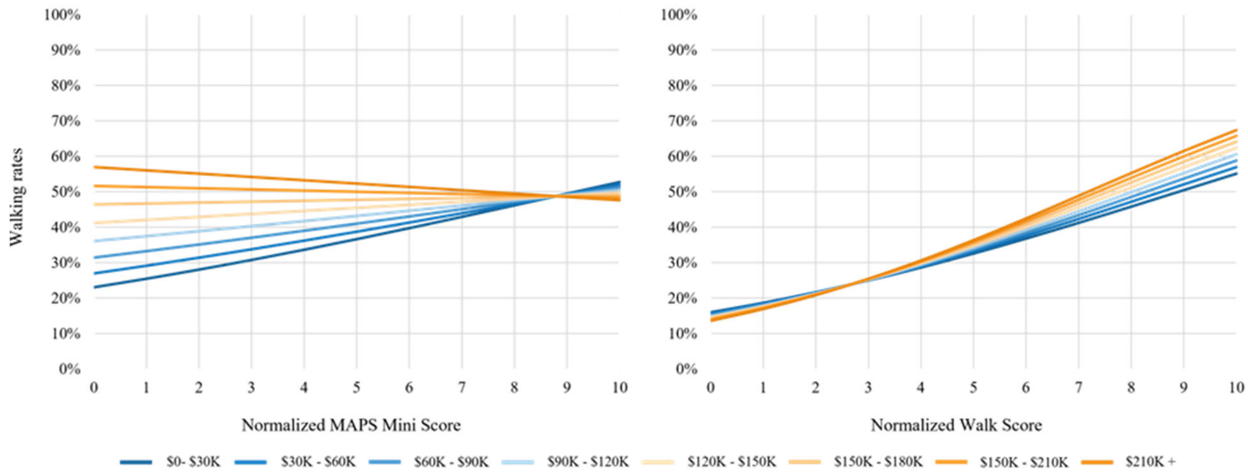

Figure 4 Walking rates prediction from interactions between median household income and walkability indices

The observed reversed effect of the MAPS-Mini audit tool on walking rates across income groups does not align with the literature as it would have been assumed that lower income individuals would walk more in areas with poor micro-scale environments as it is the case with local accessibility due to a lack of accessible alternatives both financially and geographically (*4*). Past research has also highlighted a weaker effect of local accessibility measures on lower income groups (*13*) with this reduced effect being potentially attributable to increased gentrification as high-level of physical walkability have been associated with heightened socio-economic distress in local residents (*16*). As such, while increase in Walkscore© promotes inequitable impacts along socio-economic status, this tool better explain variation in walking rates between socio-economic groups than the MAPS-Mini audit tool and aligns more with previous research.

4.4 Presence of children in the household

The interactions between the number of children aged below 13 years old in a household with Walkscore© (OR = 0.98, 95% CI [0.96-1.00]) and with the normalized MAPS-Mini score (OR = 0.94, 95% CI [0.91-0.98]) were both statistically significant ($p<0.020$ and $p<0.002$ respectively), all else being equal. This meant that for every added child under 13 in a household, the increase in walking rate was 2% smaller per incremental increase of the normalized Walkscore and 6% smaller for every incremental increase in the normalized MAPS-Mini score. In both cases, the gap in walking rates between people with different numbers of children in the household increases as the walkability improves (Figure 5).

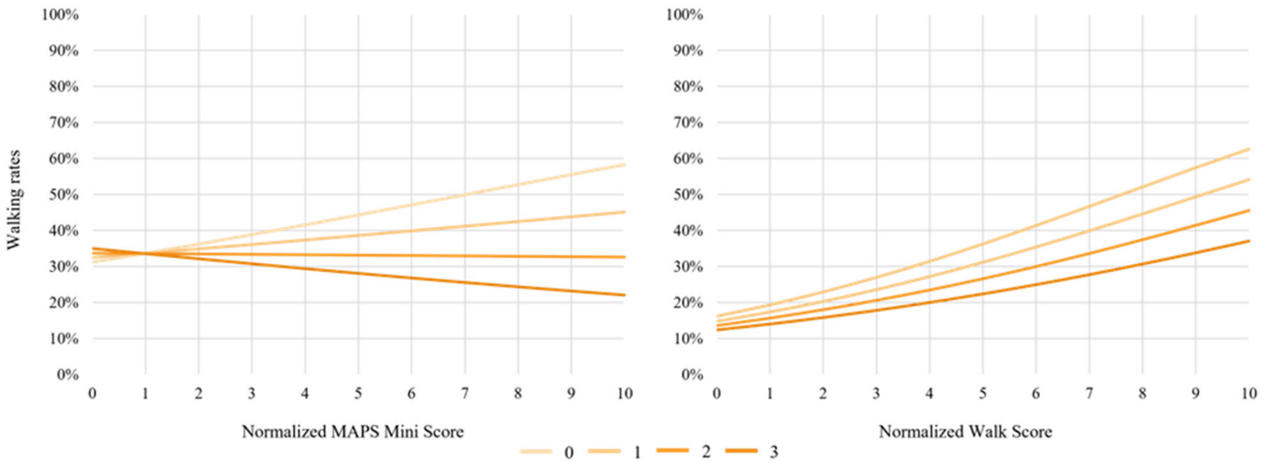

Figure 5 Walking rates prediction from interactions between the number of children below 13 years old in the household and walkability indices

The negative effects observed for the presence and the number of children in the households on walking rates for adults are coherent with past scholarship (*36; 41*). Past research has highlighted that walkability – while it can have a beneficial impact – is not amongst the primary limiting factors to active travel in children and consequently their parents (*37; 38; 41*). Parental perceptions of safety both in term of criminality and traffic play a bigger role in children's mobility with car travel being generally perceived as safer (*37-40; 42; 43*). Consequently, access to cars also play an important role in mitigating the relationship between children and their parents' active travel behaviors (*41; 47*). To that aspect, both Walkscore© and the MAPS-Mini audit tool reflect the expected differences in walking rates expected between the people living with young children and those that do not.

5. DISCUSSION

Our analysis points towards differential impacts of walkability indices on adults' walking behavior based on individuals' identities in term of gender, age, income, and number of children in a household. It also highlights how these indices vary in their ability to explain walking rates variation described in the literature. This suggests that the choice of one index over another as the determining factor behind the location and nature of walking environment interventions will shape which social group benefits the most from it.

While the gendered effect of the micro-scale built environment is coherent with differences between women and men as it pertains to attitude towards safety, neither walkability index used helps explain the component of the gendered walking patterns that is attributable to mobilities of care (*29; 31*). Despite the increased level of women in the work force, this one-sided distribution of care tasks still persists today which adds an additional constraint on women's mobility as they have to reconcile commuting with care trips on a daily basis (*29-31*). This therefore suggests that walkability as assessed through proxies of the built environment only might not be sufficient to effectively understand women's walking behavior and that more social contextualization is necessary in walkability research to better reflect gendered realities.

Similar to gender, the micro-scale built environment is also better at explaining the age differences in walking rates, which have been primarily attributed to variations in perceptions of safety and comfort in conjunction with heighten vulnerability to injuries with aging. As such, a shift from a predominant focus on increased local-accessibility – which has been shown to have a detrimental impact on older adults' walking rates when extremely high (*35*) – towards micro-scale improvements of the built environment could promote equity across age groups and help alleviate the reduction of walking rates with age.

The contradictory nature of the interaction between income and the micro-scale built-environment with the current literature could be attributed to a lack of research analyzing the interaction between walking rates and micro-scale walkability that integrate income considerations. Indeed, while low micro-scale walkability mostly with car-centric suburban settings which tend to be higher income (*21*), past research has also shown that people in low-income areas are reporting poorer micro-scale environments in term of esthetic, perceived safety or walking infrastructure (*48*). These seemingly contradicting realities point towards a need for disaggregation of micro-scale characteristics forming the MAPS-Mini audit tool to evaluate their spatial distribution and individual contribution to walking behaviors. It could also point toward the limitation of micro-scale indices to reflect income differences in walking behaviour.

While both walkability index were shown to capture the negative effect of added children in the households on walking rates, neither measure provide clear pathways for walkability measures as it stands to better promote walking in young parents and their children. With the built environment being behind numerous social perceptions and norms in term of influence on parents and children mobility, more is needed than solely increasing micro and meso-scale walkability to increase walking in this demographic. Societal actions such as the securitization of neighborhoods – both objectively and subjectively – and educational campaigns on safe walking habits could have a greater impact on changed walking behaviors for young children and their families (*36; 37; 42*).

Lastly, as previewed in the methodology, the O-D survey used present limitations in the data collected. First, the assumption that had to be made of gender corresponding to sex due to the lack of differentiation in the O-D-survey means that some respondents will have been misgendered in the analysis as they were in the data itself. Additionally, the O-D survey does not provide any information on ethnicity or immigration status which are relevant components of one's identity that could have impacts on their walking behaviour. Future iterations of this survey should include such considerations among others to allow for more thorough and inclusive research of travel behaviours. Furthermore, it should be noted that the time-consuming process of collecting the MAPS-Mini audit tool, represents a major limitation to conducting such a study on a larger scale. The constraint of the study area has limited the sample size meaning that sub-samples based on intersectionality of multiple socio-demographic and socio-economic factors were not possible even though such interactions have been shown to be important (*5; 31*). Finally, the interactions highlighted in this paper are from a higher-income country perspective which is important to acknowledge as interactions between socio-demographic and socio-economic variables with the built environment and walking behavior varies based on the regional context (*28*).

6. CONCLUSION

Overall, this paper highlights the importance of considering individuals' identities when assessing the impact of the built environment on walking as well as the incidence that choosing a specific walkability index can have on the potential to explain and address walking inequities. People have differential interactions with the built environment based on their own identity and different social groups such as women, children, older adults, or parents have unique travel experiences and perceptions that differ from whose lived experience is taken into account when designing walkability metrics. As such, over-simplification of the complex nature of walking behavior as the product of walkability proxies without contextualization of the individuals identity, can lead to an increase in social inequities.

Given our findings, we support calls from previous studies that the choice of walkability indices and what is considered to be walkable should be more theoretically grounded (*1; 2*). Additionally, we strongly suggest that demographics, while not a characteristic of the walking environment, be integrated not as controls but as mediating variables of the effect of the built environment on walking behavior and that intersectionality of those characteristics be considered. Lastly, we suggest that future research should explore ways of automating the data collection process of micro-scale built environment features using computer vision and artificial intelligence methods.

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8. AUTHORS CONTRIBUTION

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

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1