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Walkability, Complete Streets, and Gender: Who Benefits Most?

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Abstract

Does street walkability and a new complete street renovation relate to street use and gender composition? We audited two mixed-walkability complete streets (“complete less-urban” and “complete-urban”), one low-walkable street, and one high-walkable street at pre-renovation and twice post-renovation. Complete street users increased, especially for the complete-less urban street. Typically, the high-walkable street attracted the most and the low-walkable street attracted the fewest total people, males, and females; complete streets were in between. On blocks with people, females were only 29% of users; females were much less common on low-walkable streets. Street improvements might enhance gender equity.

Keywords

Active travel; walking; pedestrian; sidewalk; built environment

1. Introduction

Over 900 U.S. jurisdictions have adopted “complete street” policies that are intended to support active travel by pedestrians, cyclists, and transit riders by improving built environment and policy supports for walking, cycling, and using transit (Izenberg and Fullilove, 2016; Moreland-Russell et al., 2013; Smith et al., 2010). Several countries in Europe have also enacted policies to encourage active travel by improving streets, paths, and

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busways (Department of Health and Department for Transport, 2010; Goodman et al., 2013; Goodman et al., 2014). As policies and designs for active travel become more popular, complete street renovations and walkable designs require evaluation of use, including assessments of gender equity. The current study evaluates a new complete street renovation along with more and less walkable streets and assesses use by gender.

Lively streets are valued by health researchers for inspiring more walking (Adlakha et al., 2015) and by urban designers for enhancing city livability. Jane Jacobs valued the “sidewalk ballet” among regular users that makes a street enjoyable and friendly and the “eyes on the street” that created safety (Jacobs, 1961). Jan Gehl pedestrianized streets to create “life between buildings” (Gehl, 2011). William Whyte argued that social and physical features of high-quality public spaces attract more people, and especially females, but without formally evaluating walkability as currently understood (Whyte, 1980). These concepts and studies suggest that complete and walkable streets may attract more people overall and more females in particular.

To date, most walkability studies have related overall neighborhood walkability to physical activity (Badland and Schofield, 2005; De Nazelle et al., 2011; Hajna et al., 2015). There are two limitations to this approach. First, the geographic area used to define neighborhood walkability is often different from the areas where a resident attains physical activity. Second, studies often assess walkability in a fairly large, macro-level area (e.g., census tracts or zip codes), defining walkability as higher levels of population density, land use diversity, and street connectivity (Cervero and Kockelman, 1997). While useful, these indicators of walkability are incomplete, ignoring many of the micro-level features that Jacobs, Gehl, and Whyte emphasized, such as shade from street trees or views of aesthetically pleasing features on the street. The current study overcomes these two limitations by having trained raters count people using particular streets chosen to differ in walkability, with initial walkability assessed by trained raters using comprehensive micro-level walkability audits. We examine whether streets that differ in walkability have different numbers of total users, females, and males.

In addition, two of the four streets observed in the study had complete street renovations after the baseline observations, allowing us to test whether the renovations are followed by greater use. To clarify terminology, walkability involves design qualities that support walking, such as better aesthetics, traffic safety, crime safety, dense and diverse locations, and pedestrian facilities, such as sidewalks and transit stops (Day et al., 2006). Complete street designs are a subset of walkable designs, those intended to support pedestrians (or other active users) in the presence of automobiles (Smith et al., 2010). Walkable designs more broadly would also include a school grounds or pedestrianized street that bans cars. The present paper examines four streets that vary in walkability in the context of streets with automotive traffic; two of the streets received complete street renovations to make those blocks more attractive to pedestrians, transit riders, and cyclists.

Few walkability studies have been conducted at this level of detail and the few relevant studies have yielded mixed results and contained important limitations. For instance, following a California complete street renovation there was no increase in cyclists, but a

37% increase in pedestrians (Shu et al., 2014); these mixed findings are difficult to interpret because no comparison street was included to control for potential shifting of transportation practices over time. Although street renovations are sometimes related to more self-reported walking (Pazin et al., 2016) or accelerometer-measured walking (Brown et al., 2016), other studies show no increased use after street renovations (Boarnet et al., 2013) or greenway construction (West and Shores, 2011, 2015). Past evaluations of the complete street reported in the current study showed more nearby residents used complete street transit than before (Brown et al., 2015), and more people were counted at transit stops than before (Werner et al., 2016). Some research has related more pedestrian counts in New York City to walkable features on the block such as street furniture and multiple windows facing the street (Ewing et al., 2016); however, other research in a Midwest city has shown higher pedestrian counts related to less walkable features, such as graffiti and litter (Suminski et al., 2008). In sum, few studies systematically assess walkability of streets or paths as related to the total number and gender composition of street users over time.

The current study addresses these limitations and additionally fills a gap by counting females and males on streets that vary in walkability. It is important that females feel safe and comfortable on city streets as these locations provide opportunities to engage in physical activity through commutes, chores (e.g., trips to stores or banks), and recreational activities. Both a recent meta-analysis (Murtagh et al., 2015) and a U.S. national study using objective health measures (Furie and Desai, 2012) confirm that walking is beneficial for many health outcomes, such as body mass and diabetes risk. However, women generally achieve less physical activity than men (Furie and Desai, 2012; Troiano et al., 2008). Ensuring that women have access to environments that are supportive of their physical activity helps to promote gender equity for physical activity and health outcomes.

Unfortunately, street avoidance or unease continues to be a concern, especially for women (Pelclová et al., 2014; Van Dyck et al., 2015; Van Dyck et al., 2013). Indeed women have reported that they are especially likely to experience public hassles or incivilities (Bastomski and Smith, 2016) and consequently avoid public spaces (Koskela and Pain, 2000; Valentine, 1990), or certain streets (Pain, 1997). Although female employment has increased in past decades thereby increasing their presence outside the home (Hampton et al., 2015), females still may spend more time at home and less time outside the home than males (Drummond, 2000; Scraton and Watson, 1998; Spalt et al., 2016). Few studies have tracked the gender equity in the use of public spaces such as streets and sidewalks.

Of the few studies that assess street use by gender, females are often not quite half the users. In the small town of Wilkes-Barre Pennsylvania (population 40,000), 46% of downtown pedestrians were female (Schasberger et al., 2012). A replication of Whyte's famous 1979–1980 street use studies showed that, in 2008–2010, the proportion of females across four eastern city sites (New York City, Philadelphia, and Boston) was 40%, 43%, 47%, and 59%, with only the Metropolitan Museum steps having more women than men (Hampton et al., 2015). Thus, we also examined block-level proportions of females.

In sum, we test the following aims:

1. Compared to less walkable streets, do more walkable streets have more total people and females?
2. Does street use increase following complete street renovations, and is the increase sustained?
3. Are proportionately fewer females than males using streets and does this vary by walkability?

2. Methods

2.1 Sites

We counted people using four street sections—contiguous linear parts of a street—in Salt Lake City, Utah during October/November in time 1 (2011), time 2 (2013), and time 3 (2015). By April 2013, a complete street renovation had added a light rail line with five new stops, bike lanes, and improved sidewalks to two of the street sections; the other two street sections were not renovated. Each street section was divided into street segments—the length of one side of the street between two intersections. The four street sections had some businesses that might be more appealing to females (e.g., a yoga studio) but these were often balanced by those appealing more to males (e.g., a fly-fishing store), thus we did not detect any overall gender bias in the land uses across the streets.

The complete street renovation took place on North Temple Street, with east and west ends treated as distinct street sections. The ten eastern street segments (1.6 km, from 600 West to 1200 West), border the central business district and are more urban, and thus called the “complete-urban” street. Walkable features include multistory apartments and condominiums, a mobile home park, offices, druggists, and grocery stores. Less walkable features include undeveloped fields, drive-through businesses, and light industrial complexes. Budgetary constraints limited some landscaping and aesthetic improvements to the complete-urban street. The nine western street segments (1.7 km, from 1200 West to 2200 West) are less urban and thus called the “complete less-urban” street. It has some low-rise residential units, small businesses, government buildings, and industrial land uses. Both streets offer mixed walkability conditions and vary between 2 to 4 lanes of traffic with speeds between 30–35 mph. Although some sections of the road were closed at times in 2011 for complete street construction, major construction occurred in short stretches and pedestrian access was maintained throughout.

Two comparison street sections, without complete street renovations, represented both low-walkable and high-walkable streets; both started 10 blocks south of the complete street. Low-walkable Redwood Road (starting from 900 South to 1700 South) has eight street segments (2 km). Low-walkable features include 4 lanes of traffic, 40 mph speed limit, commercial uses mixed with empty fields and long street segments with some missing sidewalks. Many sites were automobile-oriented, such as gas stations, a car wash, and businesses with drive-through windows, while others might attract automobiles and pedestrians, such as small strip malls.

High-walkable 900 South (from State Street to 1100 East) has 20 street segments (2.4 km). Walkable features include many short street segments, 25–30 mph speed limits, complete sidewalks, several small businesses, restaurants and bars, mostly single-family detached homes, street trees, and a large public park.

2.2 Site walkability audits

To confirm that the sampled routes represent high, mixed, and low walkability, trained raters audited time 1 walkability. Over 160 items on the Irvine Minnesota Inventory (IMI) (Boarnet et al., 2006) were dichotomized (either 1 = presence of a good walkability feature and 0 = neutral walkability feature, or –1 = poor walkability feature and 0 = neutral or 1 = good; scoring details available from the corresponding author). Resulting variables were then summed into six subscales. The subscales had acceptable levels of inter-observer reliability according to intraclass correlation coefficients (ICCs): population density (ICC = 0.97), diverse destinations (0.80), accessibility (0.94), attractiveness (0.92), traffic safety (0.90), and crime safety (0.86) (Boarnet et al., 2011; Day et al., 2006).

2.3 User count procedures

Trained observers walked the sidewalks during clement weather, using a modified Block Walk Method by Suminski et al (Suminski et al., 2006). Metronome beats, tailored to each observer's stride length, timed each observer's steps to assure the same slow 1.5 mph walking speed to accommodate data collection. Observers recorded each person by gender, when possible, when they crossed the observer's horizontal plane. Counts included all users on the street, but not those in cars or buildings. Due to wide streets, each side of the street was counted separately, ending at the street centerline, resulting in 94 distinct segment sides. Observers collected data on multiple streets to reduce bias. The authors' Institutional Review Board approved the study protocol.

Consistent with other user count research (Cohen et al., 2016), observation time-blocks were scheduled for typically busy daylight times and to fulfill power calculations (weekdays 7:00–9:00 AM, 11:30 AM to 1:30 PM, 3:00–5:00 PM, and 5:00–7:00 PM; weekends 9:00–11:00 AM, 12:00–2:00 PM, and 5:00–7:00 PM). To enhance measurement stability, each time-block was counted three times across different days. Counts were then summed across the three observation days and averaged (averages > 0 but < 1 were rounded up to 1).

2.4 Measures

All counts of total people, females, and males were calculated per 180 m, the average sized street segment in this study, measured between intersection centerlines. Inter-observer reliability scores were acceptable for total people (85% agreement, ICC = 0.97), females (89% and 0.95), and males (86% and 0.98). Note that the “total people” measure would include the few instances (0.4% of all observations) when an observer could not determine gender of the street user (e.g., infants in strollers). Proportion females was calculated as number of females divided by the total number of males plus females observed on blocks where people were present.

Population density, temperature, and side of street were control variables. Segment-level population densities were estimated by summing homes and apartment units for 2011 tax parcel centroids within 1000 M street network distances from street centerlines (ESRI ArcGIS 10.1). Densities were divided into quartiles scored one to four (low-walkable M = 2.63, complete less-urban M = 1.89, complete urban M = 2.90, high-walkable M = 2.45). Average temperatures were: time 1 M = 57°F (44–73 range, SD = 8.61), time 2 M = 54°F (46–64, SD = 5.36), and time 3 M = 63°F (49–79, SD = 7.61) (Weather Underground, 2016); grand-mean centered temperatures were used in the analyses. To provide comparative analysis of proportion of female users, we report neighborhood gender composition data for residents from the American Community Survey (ACS) 5-year estimates, based on 2010–2014 block groups surrounding the streets. Similarly, we report descriptive census data for percentage employed and census tract data for commute modes for all nearby residents (the latter data were not available for the smaller census block group geography).

2.5 Statistical analyses

The unit of analysis was each of the 94 street segment sides, with time –both years and timeblocks--nested within street segment sides. Separate multilevel analyses of weekdays and weekends were conducted, controlling for population density, temperature, and side of street. Random effects were calculated for street segment side. Thus, weekdays resulted in 1128 observations (3 years X 4 time-blocks X 94 segment sides) and weekends resulted in 846 observations (3 years X 3 time-blocks X 94 segment sides).

To evaluate aims 1 and 2 for total people, females, and males, counts of users were analyzed by generalized linear mixed analyses (Long and Freese, 2006). These analyses used negative binomial models with robust standard errors due to large variances in counts (Appendix Table 1), and no offset variable was used because data were standardized as rounded counts of people per 180 m. To evaluate aim 3 for street segments with females and/or males present, the proportion of females per street segment was analyzed by linear mixed models (West et al., 2014). All models tested for main effects of street and time (focusing on changes from baseline time 1), as well as street by time interactions (using GenLinMix and Mixed procedures in SPSS v22, Armonk, NY).

3. Results

3.1 Objective walkability

Prior to testing the aims, sums of 2011 IMI walkability audit subscale scores were used to confirm the walkability categories of sampled streets. Appendix Table 2 shows that the high-walkable street scored the highest on all 6 IMI walkability scales: population density, diverse destinations, accessibility, attractiveness, traffic safety, and crime safety. The low-walkable street had the lowest scores on all 6 IMI walkability scales. The complete-urban and less-urban streets scored between the other two streets. Thus, the initial goal of selecting low and high walkable comparison streets was confirmed by audit data.

3.2 Compared to less walkable streets, do more walkable streets have more total people and females?

If more walkable streets attract more total people and females (aim 1), people counts will yield a supportive street main effect (collapsing across time). For comprehensiveness, Table 2 below also includes counts for males, although we did not hypothesize whether males favor use of more walkable streets. The estimated means feature superscripts that demonstrate which cells differ within each 4-row panel, based on pairwise tests.

For total people, the low walkable street always had significantly fewer people than the other streets with more walkable features. The complete-less urban also typically had fewer people than the complete-urban and high-walkable streets, which had the most people.

For females and males, shown in the lower panels of Table 1, the low walkable street always had significantly fewer users than the other streets with more walkable features. The complete-less urban also had fewer users than the complete-urban. The complete-less urban had fewer numbers of females, but not males, than the high-walkable street. The complete-urban and high-walkable streets had the most females and males, and showed two significant differences. The complete-urban had more weekday males than the high-walkable; the high-walkable had more weekend females than the complete-urban. Thus, the most consistent difference is that the low-walkable street has fewer females and males than all other streets. For females the complete-less urban has less use than the two most walkable streets; for males, the complete less-urban has less use than the complete-urban street.

Due to the presence of significant street by time interactions on weekdays and weekends, Appendix Table 3 describes differences across streets with separate tests for total people, females, and males at each time point. These analyses also highlight that similar walkability differences across streets were present at baseline, when the comprehensive walkability data were collected. These results at baselines were largely consistent with the overall analyses described above. For total people and females, the low-walkable and complete-less urban streets often had the lowest estimated counts, and the complete-urban and high-walkable often had the highest counts. For males, the low-walkable street typically had fewest males and the complete urban often had the most males.

3.3 Does street use increase following complete street renovations, and is the increase sustained?

If complete street renovations attract more people (aim 2), there should be post-renovation increases on the complete street yielding significant street by time interactions. Street by time interactions and street main effects for total people were all significant (Weekdays: Street $F(3,1113) = 11.52, p = .001$; Time $F(2,113) = 3.59, p = .028$; Street X Time $F(6,1113) = 3.69, p = .001$; Weekends: Street $F(3,831) = 8.88, p = .001$; Time $F(2,831) = 4.46, p = .012$; Street X Time $F(6,831) = 7.07, p = .001$). Note from the estimated counts in Table 1 that the high-walkable and the complete-urban streets had similar time 1 counts, as did the low-walkable and the complete less-urban streets.

Although the low-walkable and high-walkable streets had no complete street renovations, they did show changes in use over time. The low walkable street had declines in use by time

3 for both weekdays and weekends. The high walkable street had increases in weekend use by time 2 and increases from baseline were sustained at time 3. Thus, for these two comparison streets, the changes over time were consistent with their walkability status, with decreasing numbers of users on the low walkable and increasing numbers of user on the high walkable street.

The complete less-urban street, which had similar baseline counts to the low-walkable street, had a significant increase in users by time 2 for weekdays, and by both time 2 and 3 for weekends. The complete-urban street, which had similar baseline counts to the high-walkable street, had significant increases for weekday users by time 2.

Although we did not hypothesize that street changes over time would differ by gender, Table 2 also provides the analyses separately for counts of females and males. For females, results for total people replicate, except that females did not show a significant change over time on weekends (Weekdays: Street $F(3,1113) = 15.78, p = .001$; Time $F(2,113) = 5.60, p = .004$; Street X Time $F(6,1113) = 2.18, p = .043$; Weekends: Street $F(3,831) = 9.83, p = .001$; Time $F(2,831) = 0.75, p = .474$; Street X Time $F(6,831) = 3.27, p = .004$). For males, results for total people replicate, except that males did not show a significant time effect on weekdays (Weekdays: Street $F(3,1113) = 6.46, p = .001$; Time $F(2,113) = 1.82, p = .163$; Street X Time $F(6,1113) = 4.29, p = .001$; Weekends: Street $F(3,831) = 9.02, p = .001$; Time $F(2,831) = 4.87, p = .008$; Street X Time $F(6,831) = 4.64, p = .001$).

To provide a more visual sense of changes in use over time, we mapped unadjusted means of total people to demonstrate post-renovation increases in person counts on each street segment in Figure 1. For simplicity, this figure averaged across times 2 and 3 and subtracted the baseline count. Positive scores represent increases over baseline in people counted per street segment (numbers are drawn from Appendix Table 1). The width of the bar represents proportional sizes of street segments but the counts adjust for size differences by showing counts per 180 meters. Results show visible increases in uses on the complete streets, which appear to peak near the new rail stops. A spike for weekend use of the high-walkable street (a 6.8 person increase) was apparent outside a new brew pub.

3.4 Are proportionately fewer females than males using streets and does this vary by walkability?

The analysis of aim 1 above demonstrated that more walkable streets have more males and females. However, the relative proportion of females to males requires an analysis of proportions, which have different distributional qualities than pedestrian counts. Furthermore, the data for the next analysis involve only street segments where females and/or males were counted. We tested the proportion of females in a 4 (street) by 3 (time) linear mixed model analysis. Although the proportion of males is simply 1 minus the proportion of females, a separate analysis of proportion males is reported in Table 3 to illustrate more clearly how proportions of males differ across streets and how confidence intervals compare across males and females. Overall, the grand mean estimates (which collapse across time and street) show that females made up proportionally only 0.29 of weekday users (SE 0.01, 95% CI [0.27, 0.31]) and 0.29 of weekend users (SE 0.01, 95% CI [0.27, 0.31]). Thus, proportions of males included 0.71 on weekdays (SE = .01, 95% CI

[0.69, 0.73]) and .71 on weekends ($SE = .01$; 95% CI [0.69, 0.73]). For comparison, ACS data for census block groups adjacent to the four streets show that 47% of nearby residents are female.

The proportions of females differ significantly across streets, but there were no significant time or street by time interaction effects. On weekdays ($F(3,1034) = 34.00, p < 0.001$), the 0.19 proportion females on the low walkable street was about half as large as the 0.40 proportion females on the high-walkable street, a significant difference as indicated by the superscripts in the columns of Table 3. In between those extremes were the 0.27 proportion females on the complete-less urban street and the 0.30 on the complete-urban street; these were significantly different from the high- and low-walkable but similar to each other. On weekends ($F(3,750) = 27.59, p < 0.001$), the significant difference was between the 0.42 proportion female on the high-walkable street and all other streets, which ranged from 0.21 to 0.27 proportions of females.

The differences for proportions of males across streets were largely similar to those of females, as shown in the right hand side of Table 3. What is very clear in Table 3 is that the 95% confidence intervals for estimated proportions of females and males never overlapped. Regardless of street, people using the street were more likely to encounter males than females. However, the odds of encountering females also varied across the streets. On the low-walkable street, there were 426% more males than females on weekdays (.81/.19) and 376% on weekends. On the high-walkable street there were only 150% more males than females on weekdays and 138% more on weekends. In sum, the gender balance on streets was never equal, but grew closer to equality when the street was more walkable.

4. Discussion

In past research few studies have addressed how street-level walkability in general relates to use (Lee et al., 2015) or how street renovations associated with complete streets relate to street users (Lenker et al., 2016) or whether effects of street walkability differs by gender. The current study adds to this scarce literature by addressing three questions: Does street-level walkability correspond to numbers of street users? Do substantial improvements in street walkability, in the form of complete street additions of light rail and other renovations, relate to increased use of the street? And finally, are females benefitting from street walkability and renovations as much as males?

One aim of this research was to examine whether more walkable streets attracted more total people and females. Generally, the low-walkable street had the fewest total people, females and males (see Table 1). The complete-urban and high-walkable streets typically had the highest numbers of these user groups. These results suggest that streets modifications might enhance walkability and draw more people. In our study, more walkable features related to more people seen, which aligns with results showing good walkability related to more use in New York City (Ewing et al., 2016), in contrast to results from a Midwest city showing poor walkability relating to more use (Suminski et al., 2008). In our study, the low walkable street also had some people present. We suggest that additional research is needed to understand use of less optimal walking conditions; our systematic observation method could not answer

the question, beyond gender, of who might be using and avoiding the less walkable street and why.

A second aim of this research was to examine whether a complete street renovation, which added light rail stops, a bike lane, and improved pedestrian infrastructure, was followed by increased use over the pre-renovation baseline. The complete less-urban street had few people initially, but nearly doubled in use by time 2 on both weekdays and weekends. These increases were sustained on weekends at time 3. The complete-urban street attracted many people prior to the renovation and showed an increase in use for time 2 weekdays, with no change on weekends. Overall, the complete street renovations resulted in several instances of increased use, especially for the section of the street that was less busy before the renovation.

The 2014 census data are consistent with the suggestion that the complete-urban street serves work commuters. Along the complete street 25% of commuters among nearby residents reported active travel commutes compared to 0–15% for other streets. These analyses suggest that people rely on the improved transit systems for work trips, but are increasingly attracted to the complete less-urban street itself as a weekend destination. Similar results showing a complete street post-renovation increase in pedestrians, especially for week-ends was found in a 6-block section of a complete street in Santa Monica, CA (Shu et al., 2014). Recall that, in the current study, there are several restaurants, shops, and businesses along the complete street to attract weekend users.

As noted earlier, the most walkable street saw a new brew pub opening, which might account for the increased use of the walkable street over time; it is not known why the less walkable street sometimes had fewer people over time, given that no major store closures were noted there. In the same way, we believe that the new complete street transit stops accounted for increased use of the complete street, as suggested by Figure 1, which showed higher counts around the transit stops and brew pub. Consistent with recent recommendations from health researchers (Hunter et al., 2014), we encourage more researchers to use systematic observation to track patterns of use before and after a variety of interventions that should enhance walkability, in order to establish greater generalizability for these findings.

The study utilized the Irvine Minnesota Inventory ratings of walkability during time 1 in order to establish that we had sampled high-, low-, and mixed walkability streets, as intended. By time 2, the complete street renovations enhanced walkability on those two streets, while the high and low walkability streets did not experience major renovations. The major improvement to walkability on the mixed-walkable complete streets involved the addition of a new light rail line and stops. Although transit stops are just one of many walkability indicators in the IMI, the new light rail line and stops constituted significant changes to the street, along with the improved sidewalks, bike lane, street lighting, and landscaping that accompanied the street renovation. We acknowledge that not all walkability improvements would likely yield increases in users visible on the street. Many of the comprehensive audit items, such as decorative street banners or pedestrian benches, may be less effective ways to increase user counts, although they may be effective if part of an

overall street redesign. Given the comprehensiveness of walkability audit instruments, we suspect future researchers will need to make methodological improvements to the selection or weighting of individual audit measures (e.g., through machine learning techniques, Tribby et al., 2016), in order to investigate the effects of longitudinal changes in the dozens of walkability items that might change over time.

A third aim was to test whether proportionally fewer females used the streets and whether less walkable streets attracted proportionally fewer females. The high-walkable street had almost double the proportion of females compared to the low-walkable street. Whyte had noted that the best-used plaza spaces attract more females (Whyte, 1980), which is similar to our findings from street counts. It is not clear whether females are attracted to the more walkable designs, the greater numbers of users, or both. We urge other researchers to attend to the gender composition of those using public spaces; if our findings can be replicated, simple gender counts might be used to alert planners when female proportions fall too low; such low proportions may indicate a need for improvements in walkability, destinations, or both.

We acknowledge that it is not yet clear whether these results can be generalized to other public settings. Some research has shown that women report that they walk more in walkable than less walkable neighborhoods, but not as much as men do (Clifton and Dill, 2005). Other research has shown lower proportions of females among park users (Cohen et al., 2016). However, low proportions of females in parks might simply reflect female activity preferences rather than the effects of design features within parks. It was somewhat surprising to find such marked differences in usage by gender on city streets. In comparison, the recent (Hampton et al., 2015) counts across four of Whyte's sites ranged from 40% to 59%; downtown Wilkes-Barre (Schasberger et al., 2012) had 46% females. Percentages reported in past research were not as low as the low proportions we found on less walkable streets. We suspect our intentional inclusion of less walkable streets, which were associated with low proportions of female use, partially explains the especially low proportions of females we found in comparison to past research. Indeed, the Whyte studies focused on well-used streets and plazas and the Midwestern city study by design selected busy observation points for data collection. Thus, the purposive sampling of busy places in the few past systematic assessments of gender composition in public places may have obscured gender imbalances present in less walkable streets; we urge researchers to sample both less and more walkable places to establish whether the gender imbalances in the current study replicate elsewhere.

Among employed individuals in census block groups surrounding the study streets, there was a lower percentage of female than male residents (low-walkable: 45% female (F) among employed individuals; complete-less urban: 36% F; complete-urban: 42% F; high-walkable: 48% F), which might also help explain some of the lower use of streets by females during the work week. However, the use of active travel to work was similar across genders, with 10.41% of males and 11.63% of females using active travel to work, according to census tract estimates from the 2010–2014 American Community Survey. Commute data are suggestive because they are only available for census tracts, which can extend far beyond the street and overlap along the complete street. Thus, employment but not commute mode

patterns may contribute to gender disparities, at least from local residents on the streets during the work week.

Returning to the question of gender equity--"who benefits most?"--from walkable street conditions, our answer is multifaceted. The current study shows that males used the sampled streets more than females. Past research has also shown that men walk for longer distances when walking for active transit (Wasfi et al., 2013) and achieve more minutes of moderate to vigorous physical activity (Van Dyck et al., 2015). Our results mirror these gender differences found in past research. Consequently, the increases in physical activity associated with complete streets may be more likely to benefit men. However, proportionately more females used the high-walkable streets compared with the low-walkable street. These results suggest that more walkable designs on busier streets might attract proportionately more females and extend the benefits of walking more equally to both genders.

4.1 Strengths and limitations

Few studies examine observed counts of people across years on either complete street renovations or streets that vary in their objective walkability. Pedestrian count research typically is only cross-sectional. Furthermore, each street segment was assessed 12 times on weekdays (4 time-blocks by 3 repetitions) and 9 times on weekends (3 time periods by 3 repetitions), which should enhance stability of observations. Although interrater reliability scores for categorizing street users as male or female was high (ICCs = 0.95), one reviewer noted that males are the "unmarked" gender, suggesting that observers might be biased toward higher counts of males. Findings are also limited to one city and to publicly observed data. Future research could include intercept surveys, in which pedestrians are stopped for brief surveys, to assess travel choices and motivations, gender norms for street use, more in-depth demographic information, and perceptions of the street and other users.

5. Conclusion

Walkable streets and complete street renovations are intended to encourage more non-automotive uses of the street. Indeed, walkable streets in this study had more users and complete street renovations were followed by more people observed post-renovation. Males always outnumbered females. Walkability was related to gender proportions. Specifically, female proportions doubled from the less walkable to the most walkable street. If these results replicate, urban planners and city advocates should understand that more walkable streets are more lively and gender-balanced and that complete street renovations yield greater use.

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Highlights

- Walkability audits confirmed our 4 streets varied from low to high walkability
- More users were seen on the more walkable streets.
- The complete less-urban street especially grew more popular post-renovation
- Males exceed females on all streets
- Female proportions doubled from the least to the most walkable street

Figure 1.

Schematic map of change scores in person counts (average of time 2 and 3 minus time 1) per 180 m for street segments; bar widths are proportional to actual street segment sizes.

Note. ■ indicates complete street light-rail stop.

Table 1
Estimated counts by street main effects: total people, females, and males (per 180 m)

Total people	Weekday			Weekend		
	Mean	SE	95% CI	Mean	SE	95% CI
Low-walkable	1.52 ^a	0.16	[1.23, 1.88]	1.36 ^a	0.17	[1.06, 1.74]
Complete-less urban	2.33 ^b	0.23	[1.91, 2.84]	2.03 ^b	0.21	[1.67, 2.48]
Complete-urban	3.32 ^c	0.29	[2.79, 3.95]	2.79 ^c	0.31	[2.24, 3.46]
High-walkable	2.87 ^{bc}	0.23	[2.45, 3.36]	2.75 ^c	0.24	[2.32, 3.27]
Total females						
Low-walkable	0.57 ^a	0.07	[0.45, 0.71]	0.49 ^a	0.10	[0.33, 0.74]
Complete-less urban	0.90 ^b	0.10	[0.73, 1.11]	0.82 ^b	0.11	[0.64, 1.06]
Complete-urban	1.24 ^c	0.10	[1.06, 1.45]	1.12 ^c	0.10	[0.94, 1.32]
High-walkable	1.45 ^c	0.13	[1.22, 1.72]	1.46 ^d	0.14	[1.21, 1.76]
Total males						
Low-walkable	1.34 ^a	0.14	[1.10, 1.64]	1.10 ^a	0.09	[0.94, 1.29]
Complete-less urban	1.79 ^b	0.17	[1.49, 2.15]	1.58 ^b	0.13	[1.34, 1.87]
Complete-urban	2.37 ^c	0.19	[2.01, 2.78]	2.06 ^c	0.22	[1.68, 2.54]
High-walkable	1.85 ^b	0.14	[1.60, 2.15]	1.70 ^{bc}	0.14	[1.45, 2.00]

Note. Means sharing a letter in their superscripts are not significantly different according to pairwise *F*-tests with Bonferroni significance adjustments for multiple comparisons. Estimates control for temperature, density, and side of street.

Table 2

Time Effects →					
	Baseline (Time 1)	Time 2	T2-T1 95% CI	Time 3	T3-T1 95% CI
Total people					
Weekdays					
Low-walkable	1.81	1.47	[−0.75, 0.08]	1.32^{**}	[−0.85, −0.14]
Complete less-urban	1.83	3.03^{**}	[0.34, 2.06]	2.27	[−0.21, 1.08]
Complete-urban	2.94	3.55[*]	[0.01, 1.21]	3.49	[−0.27, 1.36]
High-walkable	3.09	2.92	[−0.69, 0.35]	2.62	[−0.96, 0.01]
Weekends					
Low-walkable	1.70	1.26	[−0.96, 0.09]	1.18^{**}	[−0.90, −0.14]
Complete less-urban	1.30	2.86^{***}	[0.96, 2.17]	2.26^{***}	[0.41, 1.52]
Complete-urban	2.68	2.98	[−0.53, 1.14]	2.71	[−0.60, 0.66]
High-walkable	2.26	2.86^{**}	[0.13, 1.08]	3.22^{**}	[0.25, 1.67]
Females					
Weekdays					
Low-walkable	0.51	0.67	[−0.03, 0.34]	0.53	[−0.17, 0.20]
Complete less-urban	0.70	1.19^{**}	[0.10, 0.88]	0.88	[−0.11, 0.48]
Complete-urban	1.30	1.31	[−0.30, 0.32]	1.13	[−0.57, 0.23]
High-walkable	1.59	1.41	[−0.40, 0.04]	1.35	[−0.53, 0.06]
Weekends					
Low-walkable	0.68	0.44	[−0.56, 0.08]	0.40[*]	[−0.57, 0.00]
Complete less-urban	0.57	1.01^{**}	[0.10, 0.77]	0.97^{**}	[0.10, 0.70]
Complete-urban	1.07	1.24	[−0.15, 0.49]	1.04	[−0.34, 0.29]
High-walkable	1.18	1.44	[−0.05, 0.57]	1.82^{**}	[0.22, 1.07]
Males					

Time Effects →

	Baseline (Time 1)	Time 2	T2-T1 95% CI	Time 3	T3-T1 95% CI
Weekdays					
Low-walkable	1.62	1.29	[-0.74, 0.08]	1.15^{**}	[-0.80, -0.14]
Complete less-urban	1.43	2.22^{**}	[0.22, 1.36]	1.82	[-0.08, 0.86]
Complete-urban	2.06	2.44	[-0.10, 0.84]	2.63[*]	[0.07, 1.07]
High-walkable	1.92	1.94	[-0.33, 0.36]	1.71	[-0.53, 0.11]
Weekends					
Low-walkable	1.21	1.13	[-0.43, 0.27]	0.98	[-0.62, 0.16]
Complete less-urban	1.05	2.14^{***}	[0.66, 1.51]	1.76^{***}	[0.28, 1.13]
Complete-urban	2.10	2.09	[-0.61, 0.58]	2.01	[-0.54, 0.36]
High-walkable	1.42	1.73[*]	[0.02, 0.62]	2.01[*]	[0.11, 1.08]

Note. Asterisks and boldface for time effects depict significant differences from baseline,

* <0.05 level,

** <0.01 level,

<0.001 level. Degrees of freedom for weekdays are 1113 and weekends are 831. Control variables include density, temperature, and side of street.

Table 3
When people are present on a block, estimates of proportion females and males by street

	Proportion female			Proportion male		
	Mean	SE	95% CI	Mean	SE	95% CI
Weekday						
Low-walkable	0.19 ^a	0.02	[0.15, 0.23]	0.81 ^a	0.02	[0.77, 0.85]
Complete-less urban	0.27 ^b	0.02	[0.24, 0.31]	0.73 ^b	0.02	[0.69, 0.77]
Complete-urban	0.30 ^b	0.02	[0.27, 0.33]	0.70 ^b	0.02	[0.67, 0.74]
High-walkable	0.40 ^c	0.01	[0.38, 0.43]	0.60 ^c	0.01	[0.57, 0.62]
Weekend						
Low-walkable	0.21 ^a	0.02	[0.17, 0.26]	0.79 ^a	0.02	[0.74, 0.83]
Complete-less urban	0.26 ^a	0.02	[0.22, 0.30]	0.74 ^a	0.02	[0.70, 0.78]
Complete-urban	0.27 ^a	0.02	[0.23, 0.31]	0.73 ^a	0.02	[0.69, 0.77]
High-walkable	0.42 ^b	0.01	[0.39, 0.45]	0.58 ^b	0.01	[0.55, 0.61]

Note. Means within each column that share a letter in their superscripts are not significantly different according to pairwise *F*-tests with Bonferroni significance adjustments for multiple comparisons. Estimates control for temperature, density, and side of street.

Appendix Table 1

Total people observed by street by time: unadjusted mean counts per block

Street	Time	Minimum	Maximum	Mean	Median	SD	Variance
Weekday							
Low-walkable	0	0	8	1.86	1.54	1.64	2.69
	1	0	5	1.42	1.34	0.99	0.98
	2	0	8	1.63	1.48	1.30	1.70
<hr/>							
Complete less-urban	0	0	7	2.06	1.57	1.88	3.52
	1	1	16	3.17	2.39	2.75	7.55
	2	0	16	2.79	2.17	2.39	5.69
<hr/>							
Complete-urban	0	1	11	3.05	2.54	2.19	4.78
	1	0	11	3.68	3.23	2.25	5.08
	2	0	24	4.46	3.75	3.85	14.86
<hr/>							
High-walkable	0	0	32	3.51	2.53	4.25	18.06
	1	0	17	2.95	2.32	2.87	8.24
	2	0	45	3.31	2.39	4.43	19.59
<hr/>							
Weekend							
Low-walkable	0	0	10	1.69	1.38	1.79	3.20
	1	0	3	1.23	1.19	0.83	0.69
	2	0	8	1.48	1.19	1.58	2.51
<hr/>							
Complete less-urban	0	0	10	1.52	1.26	1.60	2.56
	1	0	11	3.00	2.59	2.10	4.42
	2	0	11	2.80	2.41	2.07	4.28
<hr/>							
Complete-urban	0	0	11	2.82	2.11	2.21	4.86
	1	0	16	3.17	2.47	2.72	7.40
	2	1	13	3.53	2.57	2.91	8.49
<hr/>							
High-walkable	0	0	11	2.29	1.79	2.19	4.81
	1	0	20	2.99	2.45	2.84	8.04

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Street	Time	Minimum	Maximum	Mean	Median	SD	Variance
	2	0	41	4.24	2.79	5.98	35.75

Note. The above means were calculated from 17,480 individual people observed across three years.

Appendix Table 2

Descriptive statistics for baseline (2011) Irvine Minnesota Inventory walkability audit scores

IMI Scale	Street Route	Walkability	Mean	SD
Population Density	Redwood Road	Low	0.00	0.00
	North Temple West	Complete less-urban	0.46	0.66
	North Temple East	Complete-urban	0.99	0.72
	900 South	High	1.77	1.30
Diverse Destinations	Redwood Road	Low	2.03	1.40
	North Temple West	Complete less-urban	3.00	2.61
	North Temple East	Complete-urban	2.48	1.48
	900 South	High	3.33	2.49
Pedestrian Accessibility	Redwood Road	Low	-0.79	1.39
	North Temple West	Complete less-urban	0.12	1.70
	North Temple East	Complete-urban	-0.26	1.63
	900 South	High	0.90	0.90
Attractiveness	Redwood Road	Low	5.67	2.65
	North Temple West	Complete less-urban	7.66	3.79
	North Temple East	Complete-urban	6.99	3.42
	900 south	High	15.69	5.50
Traffic Safety	Redwood Road	Low	2.15	2.84
	North Temple West	Complete less-urban	5.61	4.35
	North Temple East	Complete-urban	7.00	6.41
	900 South	High	15.06	6.11
Crime Safety	Redwood Road	Low	10.07	8.22
	North Temple West	Complete less-urban	11.07	6.46
	North Temple East	Complete-urban	11.19	7.37
	900 South	High	20.82	2.14

Appendix Table 3

Estimated counts by street main effects: total people, females, and males (per 180 m)

Total people	Weekday			Weekend		
	Mean	SE	95% CI	Mean	SE	95% CI
Overall						
Low-walkable	1.52 ^a	0.16	[1.23, 1.88]	1.36 ^a	0.17	[1.06, 1.74]
Complete-less urban	2.33 ^b	0.23	[1.91, 2.84]	2.03 ^b	0.21	[1.67, 2.48]
Complete-urban	3.32 ^c	0.29	[2.79, 3.95]	2.79 ^c	0.31	[2.24, 3.46]
High-walkable	2.87 ^{bc}	0.23	[2.45, 3.36]	2.75 ^c	0.24	[2.32, 3.27]
Time 1						
Low-walkable	1.81 ^a	0.25	[1.38, 2.37]	1.70 ^{ab}	0.28	[1.23, 2.34]
Complete-less urban	1.83 ^a	0.16	[1.54, 2.19]	1.30 ^a	0.20	[0.96, 1.76]
Complete-urban	2.94 ^b	0.28	[2.45, 3.54]	2.68 ^c	0.33	[2.11, 3.41]
High-walkable	3.09 ^b	0.31	[2.55, 3.75]	2.26 ^{bc}	0.23	[1.85, 2.76]
Time 2						
Low-walkable	1.47 ^a	0.16	[1.19, 1.83]	1.26 ^a	0.15	[1.00, 1.58]
Complete-less urban	3.03 ^b	0.44	[2.29, 4.02]	2.86 ^b	0.33	[2.29, 3.58]
Complete-urban	3.55 ^b	0.35	[2.93, 4.31]	2.98 ^b	0.41	[2.29, 3.89]
High-walkable	2.92 ^b	0.25	[2.46, 3.46]	2.86 ^b	0.26	[2.40, 3.41]
Time 3						
Low-walkable	1.32 ^a	0.18	[1.01, 1.71]	1.18 ^a	0.22	[0.82, 1.70]
Complete-less urban	2.27 ^b	0.32	[1.73, 2.98]	2.26 ^b	0.26	[1.80, 2.84]
Complete-urban	3.49 ^c	0.45	[2.71, 4.50]	2.71 ^{bc}	0.40	[2.03, 3.61]
High-walkable	2.62 ^{bc}	0.26	[2.16, 3.17]	3.22 ^c	0.39	[2.54, 4.09]
Total females						
Overall						
Low-walkable	0.57 ^a	0.07	[0.45, 0.71]	0.49 ^a	0.10	[0.33, 0.74]
Complete-less urban	0.90 ^b	0.10	[0.73, 1.11]	0.82 ^b	0.11	[0.64, 1.06]

Total people	Weekday			Weekend		
	Mean	SE	95% CI	Mean	SE	95% CI
Complete-urban	1.24 ^c	0.10	[1.06, 1.45]	1.12 ^c	0.10	[0.94, 1.32]
High-walkable	1.45 ^c	0.13	[1.22, 1.72]	1.46 ^d	0.14	[1.21, 1.76]
Time 1						
Low-walkable	0.51 ^a	0.90	[0.36, 0.72]	0.68 ^a	0.17	[0.42, 1.11]
Complete-less urban	0.70 ^a	0.10	[0.54, 0.91]	0.57 ^a	0.13	[0.37, 0.88]
Complete-urban	1.30 ^b	0.14	[1.05, 1.61]	1.07 ^b	0.11	[0.87, 1.31]
High-walkable	1.59 ^b	0.16	[1.30, 1.94]	1.18 ^b	0.15	[0.93, 1.50]
Time 2						
Low-walkable	0.67 ^a	0.11	[0.49, 0.92]	0.44 ^a	0.10	[0.29, 0.69]
Complete-less urban	1.19 ^b	0.18	[0.88, 1.61]	1.01 ^b	0.15	[0.76, 1.35]
Complete-urban	1.31 ^b	0.13	[1.08, 1.58]	1.24 ^{bc}	0.14	[0.99, 1.56]
High-walkable	1.41 ^b	0.13	[1.18, 1.68]	1.44 ^c	0.15	[1.17, 1.77]
Time 3						
Low-walkable	0.53 ^a	0.06	[0.42, 0.67]	0.40 ^a	0.11	[0.23, 0.67]
Complete-less urban	0.88 ^b	0.13	[0.67, 1.17]	0.97 ^b	0.13	[0.75, 1.25]
Complete-urban	1.13 ^{bc}	0.15	[0.88, 1.45]	1.04 ^b	0.15	[0.78, 1.39]
High-walkable	1.35 ^c	0.16	[1.08, 1.70]	1.82 ^c	0.23	[1.43, 2.32]
Total males						
Overall						
Low-walkable	1.34 ^a	0.14	[1.10, 1.64]	1.10 ^a	0.09	[0.94, 1.29]
Complete-less urban	1.79 ^b	0.17	[1.49, 2.15]	1.58 ^b	0.13	[1.34, 1.87]
Complete-urban	2.37 ^c	0.19	[2.01, 2.78]	2.06 ^c	0.22	[1.68, 2.54]
High-walkable	1.85 ^b	0.14	[1.60, 2.15]	1.70 ^{bc}	0.14	[1.45, 2.00]
Time 1						
Low-walkable	1.62 ^{ab}	0.21	[1.26, 2.09]	1.21 ^a	0.14	[0.97, 1.51]
Complete-less urban	1.43 ^a	0.14	[1.19, 1.72]	1.05 ^a	0.15	[0.80, 1.39]

Total people	Weekday			Weekend		
	Mean	SE	95% CI	Mean	SE	95% CI
Complete-urban	2.06 ^b	0.19	[1.72, 2.48]	2.10 ^b	0.26	[1.65, 2.68]
High-walkable	1.92 ^b	0.19	[1.58, 2.34]	1.42 ^a	0.14	[1.17, 1.72]
Time 2						
Low-walkable	1.29 ^a	0.14	[1.05, 1.59]	1.13 ^a	0.11	[0.93, 1.36]
Complete-less urban	2.22 ^b	0.28	[1.74, 2.83]	2.14 ^b	0.21	[1.77, 2.59]
Complete-urban	2.44 ^b	0.24	[2.01, 3.00]	2.09 ^b	0.26	[1.64, 2.65]
High-walkable	1.94 ^b	0.16	[1.64, 2.28]	1.73 ^b	0.17	[1.43, 2.11]
Time 3						
Low-walkable	1.15 ^a	0.17	[0.87, 1.53]	0.98 ^a	0.17	[0.70, 1.38]
Complete-less urban	1.82 ^b	0.23	[1.41, 2.34]	1.76 ^b	0.18	[1.43, 2.16]
Complete-urban	2.63 ^c	0.30	[2.11, 3.28]	2.01 ^b	0.28	[1.53, 2.64]
High-walkable	1.71 ^b	0.16	[1.43, 2.04]	2.01 ^b	0.24	[1.59, 2.53]

Note. Means sharing a letter in their superscripts are not significantly different according to pairwise *F*-tests with Bonferroni significance adjustments for multiple comparisons. Estimates control for temperature, density, and side of street.