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Pedestrian-oriented zoning is associated with reduced income and poverty disparities in adult active travel to work, United States

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ABSTRACT

Active travel to work can provide additional minutes of daily physical activity. While the literature points to the relationship between zoning, equity and socioeconomic status, and physical activity, no study has quantitatively explored these connections. This study examined whether zoning may help to moderate any income and poverty inequities in active travel and taking public transit to work. Research was conducted between May 2012 and June 2015. Zoning data were compiled for 3914 jurisdictions covering 45.45% of the U.S. population located in 471 of the most populous U.S. counties and 2 consolidated cities located in 48 states and the District of Columbia. (Sensitivity analyses also captured unincorporated areas which, with the municipalities, collectively covered ~72% of the U.S. population.) Zoning codes were obtained and evaluated to assess the pedestrian-orientation of the zoning codes. Public transit use, active travel to work, median household income, and poverty data were obtained for all study jurisdictions from the 2010–2014 American Community Survey estimates. Associations were examined through multivariate regression models, controlling for community sociodemographics, clustered on county, with robust standard errors. We found that certain pedestrian-oriented zoning provisions (e.g., crosswalks, bike-pedestrian connectivity, street connectivity, bike lanes, bike parking, and more zoning provisions) were associated with reduced income and/or poverty disparities in rates of public transit use and active travel to work. Findings from this study can help to inform cross-sectoral collaborations between the public health, planning, and transportation fields regarding zoning for pedestrian-orientation and active travel.

1. Introduction

Given that the majority of Americans (52%) do not meet the *Physical Activity Guidelines for Americans* (U. S. Department of Health and Human Services, 2008) and that nearly one-quarter of adults do not engage in any physical activity (Centers for Disease Control and Prevention, 2014; United Health Foundation, 2016), identifying strategies to facilitate increased physical activity is paramount. One policy approach for enabling activity-conducive environments is for zoning and land use or community design policies to be written to encourage or require infrastructure that would support physical activity (Committee on Accelerating Progress in Obesity Prevention, 2012; Heath et al., 2006; National Physical Activity Plan Alliance, 2016; U.S. Department of Health and Human Services, 2015).

Zoning is a key policy lever used by local governments to change community- and street-scale design (Steel and Lovrich, 2000). Historically, zoning codes were written to permit land uses based on zoning maps that divide land into specific, typically single uses (e.g., residential only uses) (American Planning Association, 2006; Schilling and Mishkovsky, 2005). However, in recent years, communities have been reforming their zoning codes to create more pedestrian-oriented neighborhoods (American Planning Association, 2006; Davidson et al., 2004; Duany et al., 2005; Form-Based Codes Institute, 2016; Norton, 2008; O'Connell, 2008; Rodriguez et al., 2006; Schilling and Linton, 2005; Schilling and Mishkovsky, 2005; Sitkowski and Ohm, 2006; Talen, 2006; Talen, 2012, 2013).

While leisure time activity is most common in the United States, additional physical activity can be garnered through active travel to work (Audrey et al., 2014; Buehler et al., 2016; Fishman et al., 2015; Moudon et al., 2007; Pucher et al., 2010). One review suggested that public transit use was associated with up to 30 additional minutes of daily activity (Rissel et al., 2012). Yet, not all communities will achieve the same rates of active travel due to differences in infrastructure and socioeconomic status (SES), although the literature on whether and how active travel varies by SES is mixed, with some studies reporting that higher income people engage in more active travel, while others report the opposite (Rind et al., 2015; Sallis et al., 2004; Sallis et al., 2009; Turrell et al., 2013; Turrell et al., 2014).

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Prior studies have described the linkage between zoning, (in)equity, health, and/or physical activity (Chriqui et al., 2016b; Northridge and Freeman, 2011; Rachele et al., 2015; Rossen and Pollack, 2012; Sallis and Glanz, 2006; Sevtsuk, 2014; Silberfarb et al., 2014; Wilson et al., 2008) and that active living-oriented zoning is associated with active travel to work (Chriqui et al., 2016a). This study seeks to build upon this prior work by examining whether zoning may help to moderate any SES inequities in active travel to work.

2. Methods

This cross-sectional study was conducted between May 2012 and June 2015. The University of Illinois at Chicago Institutional Review Board deemed that this study did "not involve human subjects" (research protocol #2011-0880).

2.1. Sample

This study included a purposive sample of all municipal jurisdictions in the most populous 496 counties and 4 consolidated cities, representing 76.04% of the U.S. population using 2010 Census population estimates. Because zoning primarily occurs at the municipal level (with county zoning typically covering unincorporated areas), the sample frame was a census of all 6438 municipal jurisdictions covering 49.14% of the U.S. population in these counties/consolidated cities. Resource constraints necessitated limiting the sample frame to municipal jurisdictions that represented at least 0.5% of their county/consolidated city's population. This reduced the sample to 4076 jurisdictions located in 472 counties and 3 consolidated cities that contained 96.75% of the full municipal sample frame and 47.54% of the U.S. population. The remaining 28.49% of the U.S. population included in the sample frame resided in unincorporated areas or very small municipalities. The sample was further reduced for jurisdictions where the zoning code was unobtainable ($n = 155$), the walkability scale (described below) could not be generated ($n = 6$), or contextual data were unavailable ($n = 1$). Thus, the final analytical sample included 3914 jurisdictions covering 45.45% of the U.S. population located in 471 of the most populous U.S. counties and 2 consolidated cities located in 48 states and the District of Columbia.

2.2. Data sources and measures

2.2.1. Zoning codes and predictors

Zoning codes effective as of 2010 (to allow a policy lag with the outcomes) were obtained via Internet research with 100% telephone verification. Information on the process used to compile the zoning predictors is presented elsewhere (Chriqui et al., 2016b). The Appendix includes the zoning code evaluation tool; inter-coder reliability was assessed at 90% agreement or better. A dichotomous (yes/no) variable was created to indicate code reform zoning (e.g., SmartCode, form-based codes, or pedestrian- or transit-oriented, or traditional neighborhood development districts). Dichotomous indicators captured whether each of nine provisions that are supportive of active travel [sidewalks; crosswalks; bike/pedestrian connectivity; street connectivity; bike lanes; bike parking; trails/paths; mixed use; and other general walkability provisions (e.g., traffic calming and pedestrian plazas)] were addressed in any zone/district within the zoning code. A summated zoning scale (maximum value = 10) was created to assess whether the given jurisdiction had code reform zoning and/or any of the nine active living-oriented provisions.

2.2.2. American Community Survey (ACS) outcomes and covariates

Jurisdiction-level measures of active transportation to work and covariates were obtained from the American Community Survey (ACS) 2010–2014 five-year estimates, which are the most precise (U.S. Census Bureau, 2015a,b). One ACS question was used to derive the outcome measures which asked: "How did this person usually get to work LAST WEEK? If this person usually used more than one method of transportation during the trip, mark (X) the box of the one used for most of the distance." The response options included: car, truck, or van; bus or trolley bus; streetcar or trolley car; subway or elevated; railroad; ferryboat; taxicab; motorcycle; bicycle; walked; worked at home; and other method. Our public transit to work outcome measure incorporates bus or trolley bus, streetcar or trolley car, subway or elevated, railroad, and ferryboat. The active travel to work outcome measure includes walked, bicycled, or the composite public transit to work measure.

Municipal-level covariates obtained from the ACS data included tertiles of median household income and population size, percentage of households in poverty, percent non-Hispanic White, percent non-Hispanic Black, percent Hispanic, median age, percent of occupied housing with no vehicle, and region. (Sensitivity analyses also controlled for unemployment, which was correlated with our income and poverty measures, and the results were not significantly different.)

2.2.3. NAVTEQ

ArcGIS 10.1 software (Esri, 2015) was used to obtain NAVTEQ 2013 data which provided jurisdiction-level counts of 4-way intersections and all street-level intersections. As a proxy for the built environment, a walkability scale was constructed from the NAVTEQ and ACS data, based on scales published elsewhere (Ewing and Hamidi, 2014; Slater et al., 2010). The walkability scale represents the sum of four density measures (i.e., the ratio of four-way intersections to all intersections, intersection density or the total number of intersections in the municipality divided by the municipal land area, and housing unit and population density) and was standardized and adjusted by a factor of one to reduce negative scale values.

2.3. Statistical analyses

All data were linked using Federal Information Processing Standards geocodes. Descriptive statistics were computed for the sample characteristics. To examine the moderated effect of income, separate linear regressions were computed for each combination of zoning policy and active transportation measure. We ran both unadjusted, bivariate regressions (Online Appendix Tables 1–4), and adjusted, multivariate regressions that controlled for the jurisdiction characteristics listed above. All regressions included interactions between the median household income tertiles and the zoning variable. The coefficients on the income tertiles show the association between the given income level and the active transportation measure without the given zoning policy, relative to the referent (high income) (column 1 in regression tables). The coefficients on the interactions show the difference in the association between the given income level and active transportation with exposure to the zoning policy (column 2 in regression tables). We also computed the sum of the tertile and interaction coefficients to show the association between the level of income and the active transportation measure when the zoning policy is present, relative to high income (column 3 in regression tables). The statistical significance of this sum was evaluated by calculating the p-value for the corresponding t-statistic. For each zoning policy, the three columns in the regression tables all come from a single regression model.

To examine the moderated effect of poverty, separate linear regressions were computed for each combination of policy and active transportation measure. As with income, we ran both unadjusted, bivariate regressions and adjusted, multivariate regressions with the same controls. The only difference in these models is that here we included an interaction between the percent of households in poverty and the zoning variable. The coefficient on the continuous poverty variable shows the association between having one percentage point more households in poverty and the active transportation measure without the given zoning policy (column 1). The coefficient on the interaction shows the difference in this association with exposure to the zoning policy (column 2). We also computed the sum of these two coefficients, which shows the association between one percentage point more households in poverty and the active transportation measure with exposure to the zoning policy (column 3). The statistical significance of this sum also was evaluated by calculating the *p*-value for the corresponding *t*-statistic. For each zoning policy, the three columns in the regression tables all come from a single regression model.

Since this study focused on municipal zoning, unincorporated county/consolidated city areas were excluded. Sensitivity analyses were run to include county/consolidated city zoning for the unincorporated areas that represented at least 0.5% of the county/consolidated city population, using the relevant county/consolidated city zoning policy coding. After accounting for two unincorporated areas where county zoning codes could not be obtained and four that were located in consolidated cities for which the walkability scale could not be constructed, the sample for these models included 4393 municipal jurisdictions and unincorporated areas covering 71.59% of the U.S. population. Because ACS data were not available for the unincorporated areas, ACS and NAVTEQ county-level estimates were used for the unincorporated areas under the assumption that the distribution of characteristics in the population of the unincorporated areas would be the same as that in the county. Adjusted and unadjusted results from these models were substantially the same as the municipal models presented herein and are shown in Online Appendix Tables 5–12.

Because the cost of living varies across jurisdictions, sensitivity analyses were run to check whether similar results to those shown herein are obtained when using a measure of relative income. Specifically, sensitivity analyses were run using tertiles of relative income as an alternative income measure, where relative income was computed as median household income in each jurisdiction divided by median household income in the county/consolidated city in which the jurisdiction was located. Moderation results from those models were very similar to those shown herein. Also, to consider the possible effect of outliers in the public transit analyses, additional sensitivity analyses were run excluding jurisdictions in the top decile of the percentage of workers taking public transit to work. Again, moderation results from these public transit models were very similar to those shown herein.

All coefficients compare having to not having the given zoning policy. Coefficients on the zoning scale compare having or not having one additional zoning measure out of the 10 studied here. All analyses were conducted in Stata S.E. version 13 (StataCorp, 2013), clustered on county, with robust standard errors. Adjusted R-squared statistics were used to compute model fit for multivariate models. We tested statistical significance at the $p < 0.05$ level or below.

3. Results

Municipal-level characteristics are presented in Table 1. The most prevalent zoning provisions were for sidewalks, other walkability, mixed use, and bike-pedestrian trails/paths. On average, zoning codes included 4.3 out of the 10 pedestrian-oriented provisions examined. Although the average rate of taking public transit or active travel to work was low, the range was quite large (Table 1). Approximately 12.5% of households were in poverty and 71.2% of persons living in the jurisdictions were non-Hispanic White. The mean of the resident median age was 38.3 years and 7.2% of occupied households in the sample jurisdictions had no vehicle available. The mean walkability scale score of 1.0 was very low but the maximum score was 23.4.

Table 1
Characteristics of municipalities[*] included in the analysis.

	n	% or mean	SD	Minimum	Maximum
Zoning provisions addressed (%)					
Code reform zoning	567	14.5	35.2	0	100
Sidewalks	3045	77.8	41.6	0	100
Crosswalks	879	22.5	41.7	0	100
Bike-pedestrian connectivity	1449	37.0	48.3	0	100
Street connectivity	1348	34.4	47.5	0	100
Bike lanes	412	10.5	30.7	0	100
Bike parking	1264	32.3	46.8	0	100
Bike-pedestrian trails/paths	2217	56.6	49.6	0	100
Other walkability	2844	72.7	44.6	0	100
Mixed use	2676	68.4	46.5	0	100
Zoning provision scale (max 10) (mean)		4.3	2.7	0	10
Active travel outcomes					
% public transit (PT) to work		3.1	5.7	0	64.1
% active travel to work (walk, bike, or PT)		6.3	7.7	0	87.2
Covariates					
Region					
West (%)		19.3	39.4	0	100
Midwest (%)		30.4	46.0	0	100
South (%)		28.3	45.1	0	100
Northeast (%)		22.0	41.4	0	100
Median household income tertiles					
Low ($17,281.00–$47,434.00)	1306	33.3	47.2	0	100
Middle (>$47,434.00–$64,924.00)	1304	33.3	47.1	0	100
High (>$64,924.00)	1304	33.3	47.1	0	100
Population size tertiles					
Small (509–6083)	1305	33.3	47.1	0	100
Medium (>6083–22,177)	1305	33.3	47.1	0	100
Large (>22,177–2,712,608)	1304	33.3	47.1	0	100
Continuous controls					
% households in poverty		12.5	7.8	0	58.2
% non-Hispanic white		71.2	23.9	0.0	100
% non-Hispanic black		8.8	14.1	0	96.1
% Hispanic		13.6	17.9	0	99.6
Median age (mean)		38.3	6.4	12.4	74.5
% occupied housing with no vehicle available		7.2	5.9	0	78.3
Walkability scale (mean)		1.0	1.0	0.0	23.4

* $N = 3914$ jurisdictions containing 45.45% of the US population located in 471 counties and 2 consolidated cities, located in 48 states and the District of Columbia.

3.1. Public transit to work

Results of the models examining the association between median household income and the percent of households in poverty, respectively, with the percent of adults taking public transit to work without and with the zoning policy moderator are presented in Tables 2 and 3. (Unadjusted models are presented in Online Appendix Tables 1 and 2.)

The adjusted median household income models indicate that low and middle income jurisdictions have significantly lower rates of public transit to work (column 1, Table 2) as compared to high income jurisdictions in the absence of the moderating influence of zoning. When pedestrian-oriented zoning is present (column 2, Table 2), it is associated with significantly higher rates of public transit use among low and middle income jurisdictions relative to high income when there is zoning for crosswalks, bike-pedestrian connectivity, street connectivity, bike lanes, and bike parking. And, for each additional zoning provision addressed, rates of public transit relative to high income jurisdictions are 0.25 percentage points greater for low and middle income jurisdictions. Column 3 (Table 2) also indicates that once adjusting for the moderating influence of these zoning provisions, the disparity in rates of public transit use is reduced for low and middle income jurisdictions as compared to high income jurisdictions. For example, without accounting for zoning for crosswalks, the rate of public transit use for low income jurisdictions was 3.61 percentage points lower than high income jurisdictions; whereas, once accounting for the zoning provision, the difference drops to 2.11 percentage points lower (a 1.5 percentage-point reduction).

The models examining the adjusted association between the percentage of households in poverty and public transit use (Table 3) were similar to the income models. Here, rates of public transit use were lower (range: −0.09, −0.13) for each additional percent of households in poverty (column 1, Table 3). However, zoning was associated with slightly more public transit use (range 0.06, 0.11) for each additional percentage of households in poverty in jurisdictions with code reform zoning or zoning for crosswalks, bike-pedestrian connectivity, street connectivity, bike lanes, and bike parking. Indeed, when these zoning provisions were addressed, the adjusted association between poverty and rates of public transit use was no longer significant (column 3, Table 3).

3.2. Active travel to work

The results of the models examining the adjusted association between median household income and the percentage of households in poverty, respectively, with rates of active travel to work are presented in Tables 4 and 5 (unadjusted models are presented in Online Appendix Tables 3 and 4). Similar to the public transit models, after accounting for the moderating influence of zoning, the disparity in rates of active travel between low/middle income jurisdictions as compared to high income jurisdictions was reduced with zoning for sidewalks, crosswalks, bike-pedestrian connectivity, street connectivity, bike lanes, bike parking, and bike-pedestrian trails (column 2, Table 4). The models examining the adjusted association between the percentage of households in poverty and rates of active travel to work showed no disparity in the absence of pedestrian-oriented zoning; however, after adjusting for the zoning moderating influence, each additional one percentage point of households in poverty was associated with higher rates of active travel when jurisdictions had code reform zoning or zoning for crosswalks, bike-pedestrian connectivity, street connectivity, bike lanes, and bike parking (column 3, Table 5).

4. Discussion

We found that the disparity in the association between median household income and poverty rates, respectively, and rates of public transit use and active travel to work were consistently lower after adjusting for zoning for crosswalks, bike-pedestrian connectivity, street connectivity, bike lanes, and bike parking. Code reform zoning was associated with a significantly lower disparity in public transit use associated with poverty, and poverty was positively associated with active travel to work when accounting for code reform zoning. This study

Table 2
Associations between median household (MHH) income and % of workers taking public transit (PT) to work, moderated by zoning policy, 2010–2014.

	(1) Adj. association between low and middle MHH income (relative to high) and % PT use when zoning policy is not addressed		(2) Δ in % PT use when zoning policy addressed		(3) Adj. association between low and middle MHH income (relative to high) and % PT use when zoning policy is addressed
MHH income tertile (ref: high)	β	95% CI	β	95% CI	B
Code reform zoning					
Low	**−3.44*****	**−4.27, −2.61**	+1.10	−0.09, 2.30	**−2.34*****
Mid	**−2.29*****	**−3.03, −1.55**	+0.87	−0.32, 2.06	**−1.42****
Zoning for sidewalks					
Low	**−3.74*****	**−4.69, −2.78**	+0.60	−0.23, 1.43	**−3.14*****
Mid	**−2.73*****	**−3.67, −1.80**	+0.72	−0.09, 1.54	**−2.01*****
Zoning for crosswalks					
Low	**−3.61*****	**−4.51, −2.72**	**+1.51****	**0.45, 2.56**	**−2.11*****
Mid	**−2.40*****	**−3.20, −1.60**	**+1.03***	**0.09, 1.97**	**−1.37*****
Zoning for bike-ped. connectivity					
Low	**−3.91*****	**−4.95, −2.86**	**+1.66****	**0.62, 2.71**	**−2.24*****
Mid	**−2.66*****	**−3.62, −1.71**	**+1.26****	**0.31, 2.21**	**−1.40*****
Zoning for street connectivity					
Low	**−3.74*****	**−4.71, −2.78**	**+1.32****	**0.41, 2.23**	**−2.42*****
Mid	**−2.56*****	**−3.41, −1.70**	**+1.14****	**0.35, 1.92**	**−1.42*****
Zoning for bike lanes					
Low	**−3.42*****	**−4.25, −2.60**	**+1.43***	**0.25, 2.62**	**−1.99*****
Mid	**−2.29*****	**−3.03, −1.54**	**+1.26***	**0.09, 2.43**	**−1.03***
Zoning for bike parking					
Low	**−3.77*****	**−4.77, −2.76**	**+1.62****	**0.46, 2.78**	**−2.14*****
Mid	**−2.55*****	**−3.48, −1.62**	**+1.16***	**0.07, 2.25**	**−1.39*****
Zoning for bike-pedestrian trails					
Low	**−3.68*****	**−4.87, −2.49**	+0.67	−0.38, 1.73	**−3.01*****
Mid	**−2.60*****	**−3.69, −1.52**	+0.72	−0.22, 1.67	**−1.88*****
Other walkability zoning					
Low	**−3.14*****	**−3.92, −2.36**	−0.15	−1.11, 0.81	**−3.29*****
Mid	**−2.19*****	**−2.87, −1.52**	+0.06	−0.89, 1.01	**−2.13*****
Mixed use zoning					
Low	**−3.30*****	**−4.14, −2.45**	+0.04	−0.63, 0.71	**−3.26*****
Mid	**−2.54*****	**−3.39, −1.70**	+0.57	−0.11, 1.25	**−1.97*****
Zoning scale					
Low	**−4.36*****	**−5.68, −3.04**	**+0.25****	**0.07, 0.43**	**−4.10*****
Mid	**−3.25*****	**−4.49, −2.02**	**+0.25****	**0.08, 0.41**	**−3.01*****

$N = 3914$ jurisdictions containing 45.45% of the US population located in 471 counties and 2 consolidated cities, located in 48 states and the District of Columbia. Coefficients in columns 1 and 2 are from the same adjusted model for each zoning provision; column 3 is the sum of the coefficients in columns 1 and 2. All models clustered on county with robust standard errors. All adjusted $R^2 = 0.53$. Adj. = models adjusted for controls presented in Table 1. Items in **bold** are statistically significant at the following levels: * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$.

Table 3
Associations between % households (HH) in poverty and % taking public transit (PT) to work, moderated by zoning policy, 2010–2014.

	(1) Adj. association between poverty and % PT use when zoning policy is not addressed		(2) Δ in % PT use when zoning policy addressed		(3) Adj. association between poverty and % PT use when zoning policy is addressed
	β	95% CI	β	95% CI	B
Code reform zoning	**−0.11*** **	**−0.16, −0.05**	**+0.08***	**0.02, 0.15**	−0.02
Zoning for:					
Sidewalks	**−0.11** **	**−0.17, −0.05**	+0.01	−0.03, 0.06	**−0.10** **
Crosswalks	**−0.12*** **	**−0.18, −0.06**	**+0.10** **	**0.04, 0.15**	−0.02
Bike-pedestrian connectivity	**−0.12*** **	**−0.19, −0.06**	**+0.10*** **	**0.05, 0.15**	−0.02
Street connectivity	**−0.12*** **	**−0.18, −0.06**	**+0.06** **	**0.02, 0.11**	−0.05
Bike lanes	**−0.11*** **	**−0.16, −0.05**	**+0.08***	**0.01, 0.15**	−0.02
Bike parking	**−0.13*** **	**−0.19, −0.06**	**+0.11*** **	**0.06, 0.16**	−0.02
Bike-pedestrian trails	**−0.11** **	**−0.18, −0.05**	+0.02	−0.02, 0.07	**−0.09** **
Other walkability	**−0.09** **	**−0.15, −0.04**	−0.01	−0.05, 0.03	**−0.10** **
Mixed use	**−0.10** **	**−0.16, −0.04**	+0.00	−0.04, 0.04	**−0.10** **
Zoning scale	**−0.14*** **	**−0.21, −0.08**	**+0.01** **	**0.01, 0.02**	**−0.13*** **

$N = 3914$ jurisdictions containing 45.45% of the US population located in 471 counties and 2 consolidated cities, located in 48 states and the District of Columbia. Coefficients in columns 1 and 2 are from the same adjusted model for each zoning provision; column 3 is the sum of the coefficients in columns 1 and 2. All models clustered on county with robust standard errors. Adjusted $R^2 = 0.53$. Adj. = models adjusted for controls presented in Table 1. Items in **bold** are statistically significant at the following levels: * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$.

supplements the mixed results on active travel-income/neighborhood disadvantage relationships reported elsewhere (Rachele et al., 2015; Rind et al., 2015; Sallis et al., 2004; Sallis et al., 2009; Turrell et al., 2013; Turrell et al., 2014), by suggesting that zoning policies could play a role in helping to moderate disparities that may exist in active travel.

4.1. Study limitations and strengths

Although we attempted to account for the inherent weaknesses in the study, it is not without its limitations. First, the sample was a purposive sample of municipalities located in the most populous U.S. counties. While this precludes generalizing the findings to all municipalities nationwide, the large sample size is a strength in that we included nearly all municipalities located in the most populous U.S. counties so it could be generalizable to incorporated areas located in large U.S. counties. Furthermore, we presented sensitivity analyses (in the online Appendix Tables) to illustrate how accounting for county-level zoning via unincorporated areas resulted in similar results. Second, this was a correlational study so causation cannot be inferred, and it is not possible to account for endogeneity (i.e., are communities with higher rates of active travel to work more likely to engage in more pedestrian-oriented zoning or does such zoning lead to higher rates of active travel or both?). Future studies will ideally examine longitudinal impacts of zoning changes on the relationship between household income/poverty and public transit use/active travel to work. Third, while we attempted to include a policy lag (zoning codes effective as of 2010, ACS data for the 2010–2014 period), the study timeline and data availability precluded a longer lag which could produce stronger effects. Fourth, this is an ecological study that made use of the best available data with available municipal-level geocodes nationally (i.e., the ACS data). The ACS data were based on household self-reported data aggregated up to the municipal level; ideally, future studies would examine the association between zoning, income/poverty, and individual-level public transit use and active travel to work. Fifth, active travel to work is only one component of active travel (American Association of State Highway and Transportation Officials, 2013). Future studies should examine the association of zoning and related policies with active travel more generally. And, sixth, while we included a measure of community walkability using proven and reliable methods (Ewing and Hamidi, 2014; Slater et al., 2010), we were unable to test the mediating effect of on-the-ground measures of the built environment that directly corresponded to our zoning measures (e.g., sidewalks, bike lanes, mixed use) due to the enormity of our jurisdictional coverage; this is an area for future study. In fact, few studies have evaluated zoning and on-the-ground effects. Some studies report on the perceived disconnect between zoning and land use (Onsted and Chowdhury, 2014; Talen, 2013; Talen et al., 2016) that may be explained due to "grandfathered in" uses, the misalignment of zoning and comprehensive planning, the enactment of piecemeal amendments that are not tied to community goals, or time-lags in development (Talen et al., 2016). In contrast, one study concluded that land use zoning was a strong predictor of urban growth (Onsted and Chowdhury, 2014). And, in an in-progress analysis that the present study team has conducted to assess the relationship between active living-oriented zoning and community walkability in a different (albeit smaller) sample of 468 communities nationwide using objectively measured street audits (Slater et al., 2013), we found that active living-oriented zoning was positively associated with more active living-oriented environments (adj. $\beta = 0.399$, $p < 0.01$). However, without the actual built environment data for this study we do not know whether zoning actually caused the reduced disparities in active travel to work. One possibility is that zoning could be a proxy for community sentiment. Although we were unable to explore this option, it is plausible that for communities with newer zoning codes, particularly new urbanist and form-based codes which are pedestrian-oriented by design, the changes may be reflective of the residents' interest in seeing their community designed to be more activity-friendly. And, given the co-benefits of activity-friendly environments (e.g., economic, environmental sustainability, health, etc.) (Sallis et al., 2015) it is also possible that the relationship between zoning and reduced disparities associated with active travel to work may be due to community sentiment, environmental changes, or some combination thereof. Future research would be well-served to explore this further.

In spite of these limitations, we also believe the study has a number of strengths including the sheer scope and nationwide coverage. This was a first of its kind study to examine the association between zoning, income/poverty, and public transit use/active travel to work across thousands of municipal jurisdictions nationwide. The enormity of this undertaking should not be understated. The findings offer new insights for the public health and urban and transportation planning fields.

5. Conclusions

In conclusion, this study builds off several national recommendations on the role that zoning, land use, and design can play in helping to create environments that are pedestrian-oriented and that support active transportation to work. The results presented herein may provide new insights into how more pedestrian-oriented zoning can help (through changes to the built environment) to reduce income and poverty disparities in rates of public transit use and active travel to work.

Table 4
Associations between median household (MHH) income and % of workers taking active transport (walking, biking, or public transit) (AT) to work, moderated by zoning policy, 2010–2014.

	(1) Adj. Association between low and middle MHH income (relative to high) and % AT use when zoning policy is not addressed		(2) Δ in % AT use when zoning policy addressed		(3) Adj. association between low and middle MHH income (relative to high) and % AT use when zoning policy is addressed
MHH income tertile (ref: high)	β	95% CI	β	95% CI	B
Code reform zoning					
Low	**−4.51*****	**−5.67, −3.36**	+1.27	−0.20, 2.75	**−3.24*****
Mid	**−2.85*****	**−3.71, −1.98**	+1.01	−0.42, 2.43	**−1.84****
Zoning for sidewalks					
Low	**−5.31*****	**−6.65, −3.98**	**+1.30***	**0.20, 2.41**	**−4.01*****
Mid	**−3.71*****	**−4.84, −2.57**	**+1.27***	**0.22, 2.33**	**−2.43*****
Zoning for crosswalks					
Low	**−4.66*****	**−5.87, −3.44**	**+1.54***	**0.18, 2.91**	**−3.11*****
Mid	**−2.92*****	**−3.85, −2.00**	+1.00	−0.20, 2.20	**−1.92*****
Zoning for bike-ped. connectivity					
Low	**−5.28*****	**−6.65, −3.91**	**+2.54*****	**1.27, 3.81**	**−2.74*****
Mid	**−3.25*****	**−4.33, −2.16**	**+1.35***	**0.24, 2.46**	**−1.90*****
Zoning for street connectivity					
Low	**−4.88*****	**−6.17, −3.58**	**+1.58****	**0.46, 2.70**	**−3.30*****
Mid	**−3.15*****	**−4.14, −2.15**	**+1.29****	**0.34, 2.24**	**−1.86*****
Zoning for bike lanes					
Low	**−4.55*****	**−5.70, −3.41**	**+2.22****	**0.69, 3.75**	**−2.34****
Mid	**−2.85*****	**−3.73, −1.98**	**+1.57***	**0.11, 3.04**	**−1.28***
Zoning for bike parking					
Low	**−4.92*****	**−6.21, −3.62**	**+2.10****	**0.73, 3.47**	**−2.81*****
Mid	**−3.14*****	**−4.16, −2.11**	**+1.35***	**0.11, 2.59**	**−1.79*****
Zoning for bike-pedestrian trails					
Low	**−5.15*****	**−6.63, −3.67**	**+1.47***	**0.23, 2.71**	**−3.68*****
Mid	**−3.34*****	**−4.52, −2.16**	+1.06	−0.00, 2.12	**−2.28*****
Other walkability zoning					
Low	**−4.24*****	**−5.38, −3.10**	−0.02	−1.26, 1.21	**−4.26*****
Mid	**−2.57*****	**−3.38, −1.75**	−0.14	−1.27, 0.99	**−2.71*****
Mixed use zoning					
Low	**−4.26*****	**−5.41, −3.10**	−0.05	−0.92, 0.82	**−4.31*****
Mid	**−3.06*****	**−4.00, −2.12**	+0.55	−0.27, 1.37	**−2.51*****
Zoning scale					
Low	**−5.77*****	**−7.40, −4.15**	**+0.35****	**0.14, 0.56**	**−5.43*****
Mid	**−3.94*****	**−5.29, −2.58**	**+0.28****	**0.08, 0.47**	**−3.66*****

$N = 3914$ jurisdictions containing 45.45% of the US population located in 471 counties and 2 consolidated cities, located in 48 states and the District of Columbia. Coefficients in columns 1 and 2 are from the same adjusted model for each zoning provision; column 3 is the sum of the coefficients in columns 1 and 2. All models clustered on county with robust standard errors. Adjusted $R^2 = 0.51$. Adj. = models adjusted for controls presented in Table 1. Items in **bold** are statistically significant at the following levels: * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$.

Table 5
Associations between % households (HH) in poverty and % workers taking active transport (walking, biking, or public transit) (AT) to work, moderated by zoning policy, 2010–2014.

	(1) Adj. association between poverty and % AT use when zoning policy is not addressed		(2) Δ in % AT use when zoning policy addressed		(3) Adj. association between poverty and % AT use when zoning policy is addressed
	β	95% CI	β	95% CI	B
Code reform zoning	0.04	−0.05, 0.13	**+0.15****	**0.05, 0.26**	**0.19****
Zoning for:					
Sidewalks	0.00	−0.09, 0.10	+0.06	−0.00, 0.13	0.07
Crosswalks	0.03	−0.06, 0.12	**+0.13****	**0.04, 0.21**	**0.15****
Bike-pedestrian connectivity	0.01	−0.08, 0.10	**+0.18*****	**0.11, 0.26**	**0.19*****
Street connectivity	0.01	−0.08, 0.10	**+0.12****	**0.05, 0.19**	**0.14****
Bike lanes	0.04	−0.05, 0.13	**+0.12****	**0.03, 0.22**	**0.16****
Bike parking	0.01	−0.08, 0.10	**+0.18*****	**0.10, 0.25**	**0.19*****
Bike-pedestrian trails	0.01	−0.08, 0.11	**+0.08***	**0.01, 0.15**	0.09
Other walkability	0.04	−0.06, 0.13	+0.02	−0.05, 0.09	0.06
Mixed use	0.03	−0.06, 0.12	+0.04	−0.02, 0.10	0.07
Zoning scale	−0.04	−0.13, 0.06	**+0.03*****	**0.01, 0.04**	−0.01

$N = 3914$ jurisdictions containing 45.45% of the US population located in 471 counties and 2 consolidated cities, located in 48 states and the District of Columbia. Coefficients in columns 1 and 2 are from the same adjusted model for each zoning provision; column 3 is the sum of the coefficients in columns 1 and 2. All models clustered on county with robust standard errors. Adjusted $R^2 = 0.51–0.52$. Adj. = models adjusted for controls presented in Table 1. Items in **bold** are statistically significant at the following levels: * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$.

Specifically, communities that are low/middle income or have a high percentage of households in poverty may modify their zoning codes to be more supportive of active travel by incorporating active-living zoning provisions to level the playing field in accessibility by providing more opportunities for active travel and public transit usage, and reduced reliance on the car. Additionally, communities could also consider reforming their zoning codes to include zones/districts such as transit-oriented developments that facilitate public transit usage and active transportation to work (Thrun et al., 2016). And, disadvantaged communities would benefit most from infrastructure that promotes walking, biking, and public transit as these modes are more affordable than owning a car. Thus, to promote equity, communities can target infrastructure improvements near disadvantaged neighborhoods to improve access to essential services and education and employment opportunities (Litman, 2016).

Conflicts of interest

The authors have no conflicts of interest to disclose.

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Appendix A. Supplementary data

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