



Communities on the Move: Pedestrian-Oriented Zoning as a Facilitator of Adult Active Travel to Work in the United States

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Background: Communities across the United States have been reforming their zoning codes to create pedestrian-friendly neighborhoods with increased street connectivity, mixed use and higher density, open space, transportation infrastructure, and a traditional neighborhood structure. Zoning code reforms include new urbanist zoning such as the SmartCode, form-based codes, transects, transportation and pedestrian-oriented developments, and traditional neighborhood developments.

Purpose: To examine the relationship of zoning code reforms and more active living-oriented zoning provisions with adult active travel to work via walking, biking, or by using public transit.

Methods: Zoning codes effective as of 2010 were compiled for 3,914 municipal-level jurisdictions located in 471 counties and 2 consolidated cities in 48 states and the District of Columbia, and that collectively covered 72.9% of the U.S. population. Zoning codes were evaluated for the presence of code reform zoning and nine pedestrian-oriented zoning provisions (1 = yes): sidewalks, crosswalks, bike-pedestrian connectivity, street connectivity, bike lanes, bike parking, bike-pedestrian trails/paths, mixed-use development, and other walkability/pedestrian orientation. A zoning scale reflected the number of provisions addressed (out of 10). Five continuous outcome measures were constructed using 2010–2014 American Community Survey municipal-level 5-year estimates to assess the percentage of workers: walking, biking, walking or biking, or taking public transit to work OR engaged in any active travel to work. Regression models controlled for municipal-level socioeconomic characteristics and a GIS-constructed walkability scale and were clustered on county with robust standard errors.

Results: Adjusted models indicated that several pedestrian-oriented zoning provisions were statistically associated ($p < 0.05$ or lower) with increased rates of walking, biking, or engaging in any active travel (walking, biking, or any active travel) to work: code reform zoning, bike parking (street furniture), bike lanes, bike-pedestrian trails/paths, other walkability, mixed-use zoning, and a higher score on the zoning scale. Public transit use was associated with code reform zoning and a number of zoning measures in Southern jurisdictions but not in non-Southern jurisdictions.

Conclusion: As jurisdictions revisit their zoning and land use policies, they may want to evaluate the pedestrian-orientation of their zoning codes so that they can plan for pedestrian improvements that will help to encourage active travel to work.

Keywords: zoning, land use, active travel, physical activity, built environment, policy

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INTRODUCTION

The *Physical Activity Guidelines for Americans* recommend that adults get at least 150 min a week of moderate intensity physical activity (PA) through activities such as brisk walking or bicycling on ground level or an area with few hills or 75 min weekly of vigorous intensity PA through such activities as running or jogging (1, 2). However, most Americans PA levels fall far below the recommendations. In fact, the majority of Americans (52%) do not meet the *Physical Activity Guidelines* and the national median of adults who do not engage in any PA is 22.6% (3, 4). Furthermore, rates of inactivity are highest among adults living in the South, which is also the region of the country with the highest rates of obesity (4). Thus, reducing the proportion of adults who are inactive and increasing the proportion of adults who meet the *Guidelines* have been deemed priorities in *Healthy People 2020* (5, 6).

Among physically active adults, walking was reported as one of the top two activities in which the majority of male and female adults reported being engaged (7). In 2011, more than 60% of adults reported walking for at least 10 min in the past week for transportation or leisure purposes (8); however, less than one-third of adults reported walking specifically for transportation purposes (9). Because walking is the easiest form of PA to incorporate into Americans' daily lives, the U.S. Surgeon General recently issued a *Call to Action to Promote Walking and Walkability* (10).

While most Americans will derive their PA from leisure-time activities, additional PA can be garnered through active travel to destinations such as shopping, work, and school (11). Active travel to work can provide additional minutes of moderate intensity PA, and it can be achieved by walking, bicycling, or through public transit use, which involves walking and bicycling to/from public transit stops to work or other destinations. Studies have reported that adults who engage in active travel to work, particularly through walking, have overall higher levels of PA as compared to adults who do not engage in active travel to work (12–15). And adults living in more walkable neighborhoods report engaging in up to 44.3 min per week of moderate intensity PA as compared to only 12.8 min per week in neighborhoods considered to be less walkable (16).

Numerous authoritative bodies have recognized the role that community and street-scale design can play in facilitating PA and active travel (10, 17–20). Community characteristics that facilitate active travel and PA include mixed-use (MU) developments and traditional neighborhood design that provide street and sidewalk connectivity and transportation infrastructure (17, 21–27). And, adult walking is associated with more compact neighborhoods with dense street connectivity and MU development (22, 23, 28–33). Whereas, less compact or more sprawling communities and communities with limited transportation infrastructure, poor street/sidewalk connectivity, lack of sidewalks or bike paths, single use zoning, and high traffic volume tend to have lower rates of active travel and/or PA (22–24, 34–36).

One of the primary tools that local planning and zoning officials have to effectuate changes to community- and street-scale design is through their zoning codes and land use regulations (37). Historically, zoning codes were written to permit land uses

based on a zoning map that divides land into specific uses, typically single-uses such as only allowing commercial developing in commercial zones or only allowing residential development in residential zones rather than allowing a mix of residential and commercial development in MU zones (35, 38). And, traditional, or *Euclidian* zoning approaches, have contributed to sprawling, automobile-reliant communities (24, 35, 39–42). Land use changes have been shown to affect people's behavior over time (26, 43) with MU, street-scale design, and accessibility and street connectivity all demonstrating important co-benefits in improving physical health (26).

Typically, local development plans (often referred to as “master,” “comprehensive,” or “general growth” plans) are developed by local planning and zoning bodies to provide a “road map” or to guide local land use planning decisions (38). Technically, plans are implemented through changes to zoning codes/regulations (38, 44). In recent years, triggered in part by the SmartGrowth and New Urbanism movements, communities nationwide have been reforming their zoning and land use codes and regulations to create more pedestrian-oriented neighborhoods with increased street connectivity, MU and higher density, open space, transportation infrastructure, and a traditional neighborhood structure (35, 38, 39, 44, 45). These zoning code reforms include traditional neighborhood developments (TND), form-based codes, the SmartCode, and pedestrian-/transit-oriented developments (POD and TOD) all with a common goal of emphasizing walkability; and promoting MU that provides easy walking access to transport, worksites, shopping, entertainment and recreation; and emphasizing amenities and infrastructure that are associated with walking and biking behaviors including street furniture, bike lanes and bike parking, and crosswalks (35, 38, 39, 46–54). Notably, the SmartCode was developed by an architecture and town planning firm in Florida and initially diffused throughout Florida and the Southern region of the country (49). Additionally, following Hurricane Katrina in 2005, many communities along the Gulf Coast had to rebuild and used that as an opportunity to revamp their zoning codes with many opting for new urbanist and form-based codes (55, 56).

To our knowledge, no study has explored the relationship between zoning codes nationwide and active travel to work. One recent study by the current authors examined the association between zoning codes and zoning code reforms and adult leisure-time PA and found that code reforms and more active living-oriented zoning provisions (e.g., zoning requirements for mixed use, bike parking/street furniture, and bike-pedestrian trails/paths) were associated with increased odds of adult leisure-time biking and walking (57). Another study conducted in 22 California cities found that MU zoning was associated with the mix, breadth, and depth of walking destinations in the mixed-use zones within the cities (58). However, neither study examined the relationship between zoning and active travel to work. We sought to address this gap by assessing the relationship between zoning codes nationwide, including zoning code reforms and active living-oriented zoning provisions, and adult active travel to work in municipal jurisdictions nationwide and separately for Southern vs. non-Southern jurisdictions. Based on the literature reviewed above, we hypothesized that adult active travel to work

would be greater in municipalities with code reform zoning and in jurisdictions with more active living-oriented zoning requirements.

MATERIALS AND METHODS

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

Sample

The initial sample frame was a purposeful sample of all municipal jurisdictions located in the most populous 496 counties and 4 consolidated cities in the U.S. which collectively comprised 75.35% of the U.S. population. However, because this study was focused on municipal zoning, 24 of the counties were dropped from the frame because they did not contain any municipalities. As a result, the sample frame was comprised of a census of all 6,438 municipal jurisdictions in 472 counties and 4 consolidated cities, which collectively covered 73.28% of the U.S. population. Due to resource constraints, the frame was then limited to only those jurisdictions that comprised at least 0.5% of each county population. The excluded cases did not differ from the rest of the sample other than the fact that they were very small jurisdictions covering very small land areas. With this restriction, the final sample included 4,076 jurisdictions located in 472 counties and 3 consolidated cities. Although the restriction reduced the municipal jurisdiction sample size, it excluded very small jurisdictions that, in aggregate, included only 3% of the population covered by the initial sample frame and less than 2% of the U.S. population. The final sample of 4,076 jurisdictions were located in 472 counties and 3 consolidated cities in 48 states and the District of Columbia, and that collectively covered 73.01% of the U.S. population.

We could not obtain the zoning code for 155 of these jurisdictions, data needed to construct our walkability scale (detailed below) for another 6, and American Community Survey (ACS) data for one other; thus, the final analytic sample included 3,914 jurisdictions in 471 counties and 2 consolidated cities in 48 states and the District of Columbia. The counties and consolidated cities in which these jurisdictions were located covered 72.90% of the U.S. population.

Data Sources

Zoning Codes

Hard or electronic copies of the zoning codes (including zoning code reforms such as the SmartCode and form-based codes) were compiled for all 3,914 jurisdictions included in the analysis between May 2012 and May 2015. In order to facilitate a lag with the active transport outcomes, we obtained zoning codes that were effective as of 2010. (Notably, while we obtained the zoning codes as of 2010 because of the time period for the zoning code collection, anecdotally we noticed that many of the codes had been in place for years if not decades prior.) All of the zoning codes were collected via Internet research with 100% telephone

follow-up to verify complete and accurate collection. In instances where the zoning code had been updated post-2010, we obtained the version in effect as of 2010.

American Community Survey

Municipal-level characteristics and active travel to work measures were obtained from the Census Bureau’s ACS 2010–2014 5-year estimates (59). The ACS is an annual survey that provides socio-demographic characteristics for each jurisdiction. We used the 5-year ACS estimates because they are available for jurisdictions of all sizes nationwide, which was necessary as our sample was restricted to all jurisdictions containing more than 0.5% of their county/consolidated city’s population, and included small jurisdictions not captured in the 1- and 3-year estimates. The 5-year estimates are also the most precise (60).

NAVTEQ

ArcGIS 10.1 software was used to access NAVTEQ 2013 data. NAVTEQ data provided counts of four-way vs. all street level intersections for each jurisdiction. These data were combined with other measures to create a walkability scale described below.

Measures

Active Transport Outcomes

Separate variables capturing the percentage of workers walking, biking, or taking public transportation to work were derived from one ACS question: “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) in 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; or other method. From this list, we constructed three active travel to work measures: walked, bicycled, or took public transit. The public transit measure was derived from positive responses to taking bus or trolley bus, streetcar or trolley car, subway or elevated, railroad, or ferryboat. Additionally, because of the low prevalence of active travel to work (see Results), we created two additional composite measures: one capturing the percentage of workers who *either* walked *or* biked to work, and another capturing the percentage of workers who took *any* form of active transportation (walking, biking, or public transportation) to work.

Zoning Elements

Master’s level urban planners reviewed and coded the zoning codes using a zoning code audit tool and detailed coding protocol developed by the study team to assess the type of zoning (code reform vs. traditional, Euclidean) and the degree to which zoning policies addressed active living-oriented provisions (see the Supplementary Material for the coding tool). Each coder was tested for inter-rater reliability and was not allowed to code independently until they reached a 90% agreement rate. Two Research Electronic Data Capture (REDCap) databases were developed to capture policy collection and coding data entry (61).

A dichotomous (yes/no) variable was created to capture whether each jurisdiction's zoning code contained zoning code reforms (e.g., SmartCodes, form-based codes, or new urbanist, pedestrian-oriented, transit-oriented, or traditional neighborhood development districts). Each zoning code was also assessed for eight types of zones/districts (code reform, commercial, mixed use, park/recreation/open space, planned unit development, public/civic/government, residential, and general zoning) and, within each zone/district, we examined whether any of the following nine active living-oriented provisions that promote PA and active travel to work were addressed: 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 measures). For each zoning code provision, a dichotomous variable was created to indicate whether the given provision was addressed in any zone/district (e.g., crosswalks addressed in any of the zones/districts examined) within the jurisdiction. We also constructed a zoning provision scale with a maximum value of 10 which equals the number of addressed provisions (maximum value of 10 = each of the 9 provisions was addressed and the jurisdiction had code reform zoning).

Municipal-Level Controls

Tertiles of median household income and population size were generated from the ACS 2010–2014 data, as were the percentage of households in poverty, percent non-Hispanic White, percent non-Hispanic Black, percent Hispanic, median age, percent of occupied housing with no vehicle available, and region. To at least partially account for the built environment in each municipality, we created a standardized walkability scale using NAVTEQ 2013 and ACS 2010–2014 data. The walkability scale was standardized and adjusted by a factor of one to reduce negative scale values and is a summated scale of four density measures: the ratio of four-way intersections to all intersections (NAVTEQ), intersection density or the total number of intersections in the municipality divided by the municipal land area (NAVTEQ), housing unit density (ACS), and population density (ACS). The walkability scale was based on the scale created by Slater and colleagues which was adapted from the scale created and updated by Ewing and colleagues (36, 62).

Statistical Analysis

The zoning, ACS, and NAVTEQ data were linked using municipal-level Federal Information Processing Standards (FIPS) geocodes. Mean levels of active travel to work by the presence or absence of code reform zoning and our nine active living-oriented zoning provisions were computed to show the unadjusted association between code reform and active living-oriented zoning and active travel to work. *T*-tests were computed with no assumption of equal variances using Satterthwaite's approximation to test the statistical significance of differences in mean levels of active transport with and without code reform zoning and each of the nine zoning provisions. Additionally, mean levels of active travel to work were computed for each level of the zoning provision scale. Finally, multivariate linear regressions were computed to examine the relationship between active living-oriented zoning and active travel to work conditional on jurisdiction controls.

Additionally, given that the highest rates of adult inactivity are in Southern states (4) and that code reform zoning emerged in the South (49, 55, 56), we wanted to assess whether there were differences in the relationship between zoning and active travel behaviors in the South vs. other regions of the country. To do so, the prevalence of code reform zoning and each of the nine zoning provisions were computed in Southern and non-Southern jurisdictions using Census regional classifications. Bivariate *t*-tests with no assumption of equal variances were used to assess whether zoning varied by Southern region vs. non-Southern region. Multivariate linear regressions linking active living-oriented zoning to active travel to work were then run separately for Southern and non-Southern jurisdictions.

All regression models were clustered on county with robust standard errors and controlled for the jurisdiction characteristics listed above. Adjusted R^2 statistics were computed to assess model fit. All analyses were conducted using Stata S.E. version 13 (63).

RESULTS

Sample Characteristics

Descriptive statistics for the sample are presented in **Table 1**. Briefly, the majority of municipalities' zoning codes addressed sidewalks (78%), pedestrian access/other walkability (73%), mixed-use development (68%), and bike-pedestrian trails or paths (57%). Zoning for the other pedestrian-related provisions ranged from 11% (bike lanes) to 37% (bike-pedestrian connectivity). Fourteen percent of the jurisdictions had code reform zoning. On average, municipalities' zoning codes included 4.27 out of the 10 possible zoning measures.

While some communities had relatively high rates of active travel to work (i.e., the maximum rates were 46.97% walking to work, 64.14% taking public transit, and 23.07% bicycling to work), on average, the rates of active travel were non-existent or very low. Across all jurisdictions, an average of only 2.65% of respondents walked to work, 3.11% took public transit to work, and 0.48% biked to work. Overall, 6.25% of respondents engaged in some form of active travel to work.

The municipalities were located in all four Census regions, and their distribution is consistent with the national distribution of population by region. On average, rates of household poverty were low (12.54%), the vast majority of communities had large percentages of non-Hispanic White residents (71.19%), the median resident age was 38.28 years, and 7.15% of occupied households reported having no vehicle available. Median household income rates ranged from a low of \$17,281 to a maximum of >\$250,000. The size of the municipalities ranged from very small (~500 people) to very large, populous cities (more than two million people). And, the mean score on the walkability scale was 1 with a maximum score of 23.39.

Bivariate Prevalence of Active Travel to Work by Zoning Measure

Table 2 presents the bivariate summary statistics of prevalence of each form of active travel to work by each zoning measure. In the

TABLE 1 | Descriptive statistics for the municipal sample.

Variable	% or mean	SD	Min	Max
Policy predictors-Zoning Provisions (%)				
Code reform zoning	0.14	0.35	0	1
Sidewalks	0.78	0.42	0	1
Crosswalks	0.22	0.42	0	1
Bike-pedestrian connectivity	0.37	0.48	0	1
Street connectivity	0.34	0.48	0	1
Bike lanes	0.11	0.31	0	1
Bike parking	0.32	0.47	0	1
Bike-pedestrian trails/paths	0.57	0.50	0	1
Other walkability	0.73	0.45	0	1
Mixed use	0.68	0.47	0	1
Zoning provision scale (max 10) (mean)	4.27	2.69	0	10
Active travel outcomes				
% Walk to work	2.65	3.41	0	46.97
% Public transit to work	3.11	5.75	0	64.14
% Bike to work	0.48	1.03	0	23.07
% Walk or bike to work	3.14	3.91	0	47.15
% Active travel to work (walk, bike, PT)	6.25	7.70	0	87.19
Jurisdiction controls				
West (%)	0.19	0.39	0	1
Midwest (%)	0.30	0.46	0	1
South (%)	0.28	0.45	0	1
Northeast (%)	0.22	0.41	0	1
% Households in poverty	12.54	7.77	0	58.24
% Non-Hispanic White	71.19	23.91	0.05	100
% Non-Hispanic Black	8.77	14.11	0	96.10
% Hispanic	13.58	17.89	0	99.61
Median household income tertiles				
Low (\$17,281.00–\$47,434.00)	0.33	0.47	0	1
Middle (>\$47,434.00–\$64,924.00)	0.33	0.47	0	1
High (>\$64,924.00–>\$250,000.00)	0.33	0.47	0	1
Median age (mean)	38.28	6.37	12.40	74.50
% Occupied housing with no vehicle available	7.15	5.90	0	78.25
Population size tertiles				
Low (509–6,083)	0.33	0.47	0	1
Middle (>6,083–22,177)	0.33	0.47	0	1
High (>22,177–2,712,608)	0.33	0.47	0	1
Walkability Scale (mean)	1.01	1.00	0.03	23.39

N = 3914 jurisdictions located in 471 counties and 2 consolidated cities representing 72.90% of the U.S. population, located in 48 states and the District of Columbia.

bivariate models, the only zoning measure that was statistically associated with increased rates of walking to work was mixed-use zoning (2.80% with mixed use vs. 2.34% without mixed use). In contrast, biking to work was significantly more common in jurisdictions with vs. without each of the zoning measures. Taking public transit to work was significantly more common in municipalities with code reform zoning and zoning provisions addressing sidewalks, crosswalks, bike parking (proxy for street furniture), other walkability/pedestrian access, and mixed-use development. Finally, in municipalities with 8 or more of the 10 zoning measures, rates of walking to work, biking to work, and engaging in any form of active travel to work were at their highest levels.

Results of the Multivariate Regression Models Examining the Association between Zoning and Active Travel to Work

The results of the adjusted models, controlling for the municipal-level controls, are presented in **Table 3**. This brief summary focuses on the primary active travel measures – walking to work, biking to work, and taking public transit to work – as well as the overall composite measure of engaging in any active travel to work. The results of the composite measure of walking or biking to work are only presented in the table for brevity reasons.

Code reform zoning was associated with increased rates of biking to work ($\beta = 0.13$, 95% CI = 0.02–0.23) and marginally associated with walking and taking public transit to work. Additionally, rates of walking to work were significantly higher in municipalities whose zoning codes included provisions for bike parking (our proxy for street furniture) ($\beta = 0.38$, 95% CI = 0.14–0.62); bike-pedestrian trails/paths ($\beta = 0.26$, 95% CI = 0.05–0.47); other walkability/pedestrian access ($\beta = 0.25$, 95% CI = 0.02–0.47); and mixed-use development ($\beta = 0.30$, 95% CI = 0.10–0.50). Only two zoning measures were marginally associated with taking public transit to work – zoning for bike lanes and for bike parking. However, rates of biking to work were significantly higher in municipalities that zoned for sidewalks ($\beta = 0.08$, 95% CI = 0.02–0.14); street connectivity ($\beta = 0.08$, 95% CI = 0.01–0.15); bike lanes ($\beta = 0.16$, 95% CI = 0.04–0.27); bike parking ($\beta = 0.30$, 95% CI = 0.21–0.38); bike-pedestrian trails or paths ($\beta = 0.07$, 95% CI = 0.01–0.13); other walkability/pedestrian access ($\beta = 0.09$, 95% CI = 0.03–0.15); and mixed-use development ($\beta = 0.12$, 95% CI = 0.06–0.18). And, a higher score on the zoning scale was associated with higher rates of walking to work ($\beta = 0.06$, 95% CI = 0.02–0.10) and biking to work ($\beta = 0.03$, 95% CI = 0.02–0.04).

Because of the low prevalence of each type of active travel to work, we also examined the association between each of the zoning measures and engaging in any type of active travel to work (walking, biking, or taking public transit), which helped to increase the prevalence a bit. In these models, we found a number of zoning measures positively associated with increased rates of engaging in any active travel to work: code reform zoning ($\beta = 0.93$, 95% CI = 0.24–1.62); bike lanes ($\beta = 1.05$, 95% CI = 0.14–1.96); bike parking ($\beta = 1.02$, 95% CI = 0.49–1.55); and other walkability ($\beta = 0.61$, 95% CI = 0.12–1.09). And, for each additional zoning provision addressed, the percentage of municipal-level residents engaging in active travel to work increased by 0.13 percentage points ($\beta = 0.13$, 95% CI = 0.04–0.23).

Results in Southern and Non-Southern Jurisdictions

Figure 1 presents the prevalence of code reform zoning and the nine zoning provisions in Southern and non-Southern jurisdictions. Code reform zoning is twice as prevalent in the South as outside it, and five of the nine active living-oriented zoning provisions are significantly more prevalent in the South at the $p < 0.05$ level or lower.

Tables 4 and **5** show the results of the adjusted models examining the association between the zoning measures and active

TABLE 2 | Prevalence of municipal-level active travel to work by zoning measure, 2010–2014.

Zoning measure (yes = zoning measure present, no = zoning measure not present)		Active travel to work mode: percentage of municipal residents to ...									
		Walk		Bike		Walk or bike		Take public transit		Active transport ^a	
		%	p*	%	p*	%	p*	%	p*	%	p*
Code reform zoning	Yes	2.91	0.064	0.69	<0.001	3.60	0.005	4.60	<0.001	8.19	<0.001
	No	2.61		0.45		3.06		2.86		5.92	
Zoning provisions addressed											
Sidewalks	Yes	2.64	0.518	0.53	<0.001	3.16	0.437	3.30	<0.001	6.46	<0.001
	No	2.72		0.33		3.05		2.46		5.51	
Crosswalks	Yes	2.58	0.496	0.56	0.023	3.14	0.962	3.51	0.044	6.65	0.126
	No	2.67		0.46		3.14		3.00		6.13	
Bike-pedestrian connectivity	Yes	2.54	0.118	0.56	0.001	3.10	0.634	3.28	0.170	6.38	0.436
	No	2.72		0.44		3.16		3.01		6.18	
Street connectivity	Yes	2.49	0.029	0.56	0.003	3.05	0.294	2.78	0.006	5.82	0.011
	No	2.74		0.45		3.19		3.29		6.47	
Bike lanes	Yes	2.64	0.902	0.75	<0.001	3.39	0.175	3.49	0.131	6.88	0.070
	No	2.66		0.45		3.11		3.07		6.18	
Bike parking (proxy for street furniture)	Yes	2.77	0.123	0.81	<0.001	3.58	<0.001	3.95	<0.001	7.53	<0.001
	No	2.60		0.33		2.93		2.71		5.64	
Bike-pedestrian trails/paths	Yes	2.58	0.117	0.57	<0.001	3.15	0.889	3.04	0.413	6.19	0.581
	No	2.75		0.38		3.13		3.20		6.33	
Other walkability	Yes	2.68	0.388	0.55	<0.001	3.23	0.014	3.41	<0.001	6.64	<0.001
	No	2.57		0.32		2.89		2.31		5.20	
Mixed use	Yes	2.80	<0.001	0.57	<0.001	3.37	<0.001	3.38	<0.001	6.74	<0.001
	No	2.34		0.31		2.64		2.54		5.18	
Number of zoning provisions addressed (zoning scale)											
	0	2.62		0.22		2.84		1.77		4.61	
	1	2.39		0.30		2.70		2.46		5.16	
	2	2.94		0.36		3.30		3.15		6.45	
	3	2.75		0.44		3.19		3.40		6.59	
	4	2.51		0.43		2.94		3.23		6.17	
	5	2.38		0.58		2.95		3.08		6.03	
	6	2.78		0.57		3.35		3.45		6.80	
	7	2.75		0.58		3.33		3.28		6.61	
	8	3.11		0.78		3.88		3.43		7.31	
	9	2.50		0.84		3.35		3.21		6.56	
	10	2.27		0.62		2.88		4.72		7.61	

*p-value generated from a t-test comparing yes to no for each zoning measure. The t-tests were only computed for the dichotomous zoning measures and not for the zoning scale.

^aActive transport to work was computed as "yes" for ANY walking, biking, or taking public transit to work. N = 3914 jurisdictions located in 471 counties and 2 consolidated cities representing 72.90% of the U.S. population, located in 48 states and the District of Columbia.

travel to work when conducted separately for Southern and non-Southern jurisdictions. While none of the zoning measures were significantly associated with public transit use in the full sample (Table 3 above), there are a number of strong significant associations when limiting the analysis to Southern jurisdictions, which do not appear among the non-Southern jurisdictions. On the other hand, results for biking to work and the composite walking or biking to work measure appear to be driven by non-Southern jurisdictions. Overall, results for engaging in any active travel to work are strongest for Southern jurisdictions, with few significant associations between zoning and active travel among non-Southern jurisdictions but strong positive associations in the South.

DISCUSSION

As far as we know, this was the first and largest study of the prevalence of code reform zoning and active living-oriented zoning by municipalities located across the United States and their respective association with rates of adult active travel to work.

This study adds to the limited but emerging literature examining the relationship between zoning and active living and health-related outcomes. It also supports the theory behind new urbanist zoning that such zoning can support more pedestrian-oriented environments and activity, in this case specifically active travel to work. In fact, code reform zoning is associated with nearly a one percentage-point higher rate of active travel to work compared to non-code reform communities. Additionally, code reform zoning and certain active living-oriented zoning measures are more prevalent in the South (where code reform zoning initially emerged) and, as such, their associations with active travel to work were also stronger in the South than in non-Southern jurisdictions, particularly for public transit use and overall active travel to work.

The results of this study also are consistent with the urban planning and active living literature that has concluded that street-scale and community-scale design features are associated with higher rates of activity or active travel. While we were unable to sufficiently measure on-the-ground design features, zoning codes provide the foundation for land use design and permitted

TABLE 3 | Adjusted association^a between municipal zoning policies and the percent of workers engaging in active travel to work, ACS 2010–2014 (full sample; N = 3914).

Zoning Measure	% Walk to work ^b		% Public transit to work ^c		% Bike to work ^d		% Walk or bike to work ^e		% Engage in active travel to work ^f	
	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI
Code reform zoning	0.24	-0.00, 0.48	0.56	-0.01, 1.13	0.13*	0.02, 0.23	0.36*	0.07, 0.66	0.93**	0.24, 1.62
Zoning provisions addressed										
Sidewalks	0.17	-0.07, 0.40	0.04	-0.34, 0.42	0.08*	0.02, 0.14	0.25	-0.01, 0.51	0.29	-0.19, 0.77
Crosswalks	0.12	-0.10, 0.35	0.11	-0.36, 0.58	0.07	-0.01, 0.16	0.19	-0.09, 0.47	0.30	-0.28, 0.87
Bike-pedestrian connectivity	0.12	-0.08, 0.33	0.12	-0.29, 0.53	0.03	-0.05, 0.10	0.15	-0.10, 0.40	0.27	-0.24, 0.78
Street connectivity	0.10	-0.08, 0.29	0.04	-0.32, 0.40	0.08*	0.01, 0.15	0.18	-0.04, 0.41	0.23	-0.21, 0.66
Bike lanes	0.25	-0.04, 0.53	0.65	-0.10, 1.40	0.16*	0.04, 0.27	0.40*	0.05, 0.75	1.05*	0.14, 1.96
Bike parking (proxy for street furniture)	0.38**	0.14, 0.62	0.34	-0.06, 0.74	0.30***	0.21, 0.38	0.68***	0.39, 0.97	1.02***	0.49, 1.55
Bike-pedestrian trails/paths	0.26*	0.05, 0.47	-0.16	-0.54, 0.21	0.07*	0.01, 0.13	0.32**	0.09, 0.56	0.16	-0.29, 0.61
Other walkability ^g	0.25*	0.02, 0.47	0.27	-0.13, 0.67	0.09**	0.03, 0.15	0.34**	0.09, 0.59	0.61*	0.12, 1.09
Mixed use	0.30**	0.10, 0.50	-0.13	-0.40, 0.15	0.12***	0.06, 0.18	0.42***	0.19, 0.64	0.29	-0.08, 0.66
Zoning scale (0–10; # items addressed)	0.06**	0.02, 0.10	0.04	-0.04, 0.12	0.03***	0.02, 0.04	0.09***	0.05, 0.14	0.13**	0.04, 0.23

^aAll models clustered on county with robust standard errors. All models controlled for region, % households in poverty, % non-Hispanic white, % non-Hispanic Black, % Hispanic, median household income tertiles, median age, walkability scale, % occupied housing with no vehicle available, and population size tertiles.

^bMunicipal-level walk to work models adjusted R² = 0.26–0.27.

^cMunicipal-level public transit to work models adjusted R² = 0.53.

^dMunicipal-level bike to work models adjusted R² = 0.12–0.13.

^eMunicipal-level walk OR bike to work models adjusted R² = 0.26.

^fMunicipal-level active travel to work models adjusted R² = 0.51.

^gOther walkability includes any type of walking or bicycling provision mentioned in a code or plan that is oriented to active living that does not include our established markers. This includes phrases including the word “pedestrian” such as “pedestrian scaled development” or “pedestrian safety.” It can also include traffic calming markers.

*p < 0.05, **p < 0.01, ***p < 0.001. Bolded items are statistically significant.

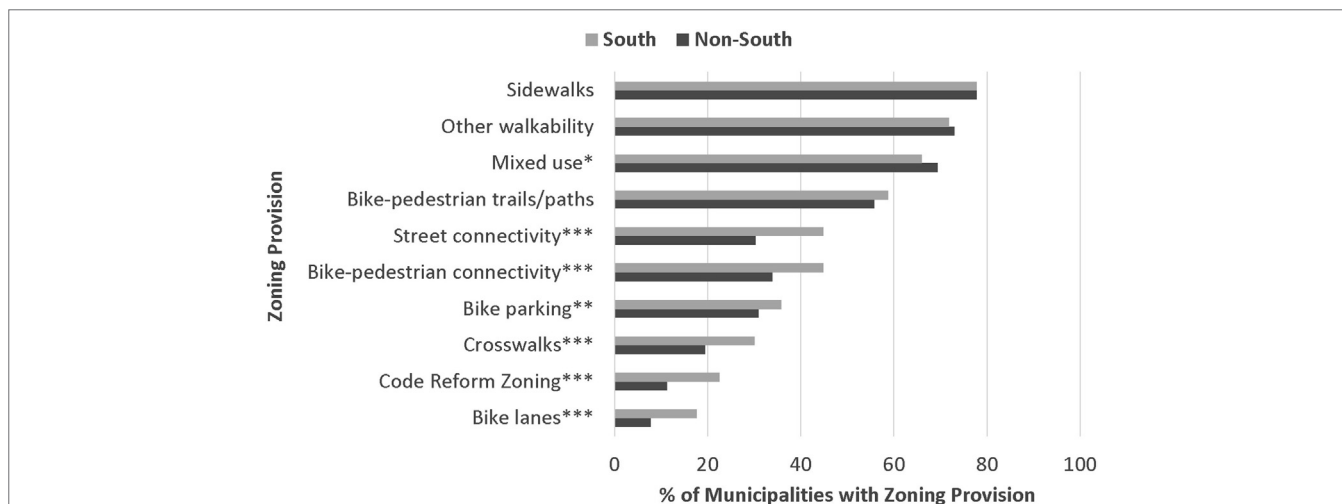


FIGURE 1 | Prevalence of zoning provisions, South vs. Non-South. N = 3914 jurisdictions located in 471 counties and 2 consolidated cities representing 72.90% of the U.S. population, located in 48 states and the District of Columbia; N = 1108 jurisdictions in the South and N = 2806 jurisdictions in non-Southern regions of the country. *p < 0.05, **p < 0.01, and ***p < 0.001; p-value generated from a t-test comparing prevalence in Southern and non-Southern jurisdictions.

land uses (35, 38, 39). Zoning is a necessary precursor to design standards and guidelines in a community. Thus, given that many of the zoning provisions that were associated with active travel to work are consistent with the types of built environment measures

associated with active travel, zoning provisions may serve as an initial proxy for measures of the built environment when they otherwise may not be readily available (as in this study). Currently, unpublished data from the study team conducted as part of the

TABLE 4 | Adjusted association^a between municipal zoning policies and the percent of workers engaging in active travel to work, ACS 2010–2014 (Southern jurisdictions; N = 1108).

Zoning measure	% Walk to work ^b		% Public transit to work ^c		% Bike to work ^d		% Walk or bike to work ^e		% Engage in active travel to work ^f	
	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI
Code reform zoning	-0.06	-0.35, 0.24	1.23**	0.41, 2.05	-0.04	-0.14, 0.07	-0.09	-0.44, 0.25	1.13*	0.12, 2.15
Zoning provisions addressed										
Sidewalks	-0.01	-0.34, 0.32	0.30	-0.03, 0.63	0.07	-0.02, 0.17	0.06	-0.31, 0.43	0.37	-0.11, 0.84
Crosswalks	0.06	-0.22, 0.35	0.60	-0.16, 1.36	0.08	-0.04, 0.20	0.14	-0.22, 0.51	0.75	-0.19, 1.68
Bike-pedestrian connectivity	0.05	-0.24, 0.34	0.55*	0.05, 1.05	0.05	-0.06, 0.15	0.09	-0.26, 0.45	0.64	-0.04, 1.32
Street connectivity	0.12	-0.14, 0.37	0.67*	0.15, 1.19	0.08	-0.02, 0.18	0.19	-0.11, 0.50	0.86**	0.21, 1.51
Bike lanes	-0.13	-0.44, 0.18	1.23*	0.02, 2.44	0.05	-0.08, 0.18	-0.08	-0.47, 0.30	1.15	-0.29, 2.59
Bike parking (proxy for street furniture)	0.17	-0.15, 0.49	1.08***	0.47, 1.69	0.19**	0.07, 0.32	0.36	-0.04, 0.76	1.44***	0.65, 2.23
Bike-pedestrian trails/paths	0.19	-0.07, 0.45	0.33	-0.02, 0.68	0.05	-0.06, 0.15	0.24	-0.07, 0.55	0.57*	0.08, 1.06
Other walkability ^g	0.19	-0.12, 0.51	0.42*	0.08, 0.76	0.06	-0.05, 0.18	0.26	-0.12, 0.63	0.68*	0.16, 1.20
Mixed use	0.11	-0.19, 0.40	0.39*	0.05, 0.74	0.08	-0.03, 0.20	0.19	-0.17, 0.55	0.59*	0.08, 1.09
Zoning Scale (0–10; # items addressed)	0.02	-0.03, 0.06	0.16**	0.04, 0.27	0.02*	0.00, 0.03	0.04	-0.02, 0.09	0.19**	0.05, 0.33

^aAll models based on multivariate linear regressions, clustered on county with robust standard errors. All models controlled for % households in poverty, % non-Hispanic white, % non-Hispanic Black, % Hispanic, median household income tertiles, median age, walkability scale, % occupied housing with no vehicle available, and population size tertiles.

^bMunicipal-level walk to work models adjusted R² = 0.13.

^cMunicipal-level public transit to work models adjusted R² = 0.44–0.45.

^dMunicipal-level bike to work models adjusted R² = 0.12–0.13.

^eMunicipal-level walk or bike to work models adjusted R² = 0.15.

^fMunicipal-level active transport to work models adjusted R² = 0.36–0.37.

^gOther walkability includes any type of walking or bicycling provision mentioned in a code or plan that is oriented to active living that does not include our established markers. This includes phrases including the word “pedestrian” such as “pedestrian scaled development” or “pedestrian safety.” It can also include traffic calming markers.

*p < 0.05, **p < 0.01, and ***p < 0.001. Bolded items are statistically significant.

TABLE 5 | Adjusted association^a between municipal zoning policies and the percent of workers engaging in active travel to work, ACS 2010–2014 (non-Southern jurisdictions; N = 2806).

Zoning measure	% Walk to work ^b		% Public transit to work ^c		% Bike to work ^d		% Walk or bike to work ^e		% Engage in active travel to work ^f	
	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI
Code reform zoning	0.34	-0.00, 0.69	0.35	-0.27, 0.97	0.24**	0.08, 0.39	0.58**	0.15, 1.00	0.93*	0.15, 1.71
Zoning provisions addressed										
Sidewalks	0.06	-0.24, 0.36	-0.14	-0.59, 0.31	0.09*	0.01, 0.17	0.15	-0.18, 0.47	0.00	-0.58, 0.59
Crosswalks	0.05	-0.25, 0.36	-0.13	-0.73, 0.47	0.07	-0.05, 0.18	0.12	-0.26, 0.50	-0.01	-0.74, 0.72
Bike-pedestrian connectivity	0.06	-0.20, 0.33	-0.10	-0.64, 0.44	0.07	-0.03, 0.18	0.14	-0.19, 0.46	0.04	-0.64, 0.71
Street connectivity	-0.06	-0.31, 0.19	-0.30	-0.73, 0.14	0.09	-0.00, 0.19	0.03	-0.27, 0.33	-0.27	-0.82, 0.28
Bike lanes	0.47*	0.03, 0.90	0.24	-0.48, 0.96	0.36***	0.16, 0.55	0.82**	0.28, 1.36	1.06*	0.13, 1.99
Bike parking (proxy for street furniture)	0.31	-0.02, 0.64	-0.06	-0.74, 0.61	0.44***	0.31, 0.56	0.75***	0.35, 1.14	0.68	-0.15, 1.52
Bike-pedestrian trails/paths	0.18	-0.11, 0.47	-0.44	-1.04, 0.16	0.14**	0.05, 0.23	0.32	-0.01, 0.66	-0.12	-0.84, 0.61
Other walkability ^g	0.11	-0.20, 0.42	0.17	-0.32, 0.65	0.14***	0.07, 0.21	0.25	-0.08, 0.59	0.42	-0.17, 1.01
Mixed use	0.26	-0.01, 0.52	-0.23	-0.58, 0.13	0.17***	0.09, 0.24	0.42**	0.13, 0.72	0.20	-0.28, 0.67
Zoning scale (0–10; # items addressed)	0.05	-0.01, 0.11	-0.04	-0.15, 0.07	0.05***	0.03, 0.07	0.10**	0.03, 0.17	0.06	-0.07, 0.20

^aAll models based on multivariate linear regressions, clustered on county with robust standard errors. All models controlled for % households in poverty, % non-Hispanic white, % non-Hispanic Black, % Hispanic, median household income tertiles, median age, walkability scale, % occupied housing with no vehicle available, and population size tertiles.

^bMunicipal-level walk to work models adjusted R² = 0.27.

^cMunicipal-level public transit to work models adjusted R² = 0.52–0.53.

^dMunicipal-level bike to work models adjusted R² = 0.10–0.12.

^eMunicipal-level walk or bike to work models adjusted R² = 0.26–0.27.

^fMunicipal-level active travel to work models adjusted R² = 0.49.

^gOther walkability includes any type of walking or bicycling provision mentioned in a code or plan that is oriented to active living that does not include our established markers. This includes phrases including the word “pedestrian” such as “pedestrian scaled development” or “pedestrian safety.” It can also include traffic calming markers.

*p < 0.05, **p < 0.01, and ***p < 0.001. Bolded items are statistically significant.

Robert Wood Johnson Foundation-supported Bridging the Gap Program supports this in that we have found that built environment infrastructure is more common in jurisdictions with active living-oriented zoning (64).

With the exception of zoning for sidewalks, the measures that were consistently associated with active travel to work were those that tended to be more prevalent in the zoning codes (e.g., bike parking, bike-pedestrian trails/paths, other walkability, and MU zoning). And, not surprisingly, zoning for well-connected streets and for bike lanes was significantly associated with higher rates of biking to work. These findings lend support to recommendations for local zoning and land use policies that support community- and street-scale design features (10, 18–20, 65). Results suggest that sidewalks alone (which are highly common) is not enough to facilitate active travel, and that communities may need built environment features that also provide better connected, and more direct routes to increase pedestrian use for work-related active travel.

Consistent with the literature, we also found that MU zoning was associated with higher rates of walking and biking to work (17, 21–26, 58). This was not surprising given that the premise behind mixed-use development is that it facilitates people living in areas where they work, shop, and play or being in close proximity to public transit that would enable them to actively commute to work.

Interestingly, rates of taking public transit to work were only marginally (at best) associated with the zoning measures in the full models; however, they were significantly associated with the zoning measures in the models restricted to Southern jurisdictions, suggesting that regional differences were masked in the full model. This is an interesting dichotomy, particularly given that rates of inactivity are higher in Southern states (4), suggesting that code reform and active living-oriented zoning may be serving as a proxy for on the ground infrastructure redevelopment that have occurred in Southern parts of the country following Hurricane Katrina, which collectively are helping to facilitate more active travel (and less inactivity) among Southern residents. Among those changes has been the prevalence of transit-oriented development (a type of zoning code reform), which would facilitate public transit use. And, one possible explanation for the lack of association with the non-Southern jurisdictions (which are less likely to have zoning code reforms or many forms of active living-oriented zoning) is that transit stops are addressed through transportation plans and design guidelines rather than being specifically addressed in the zoning codes. Future studies should consider supplementing the zoning information with other land use plans and design guidelines that would enable us to capture such information as well as complete streets policies which aim to ensure a place on the road for all users (66, 67). Additionally, future studies should seek to include measures of actual transit stops and service frequency within the communities to test implementation of such plans/design guidelines.

Study Limitations and Areas for Future Study

While we attempted to minimize the limitations of the study, given the scope of the study, it was impossible to account for them in their entirety. Thus, we recognize the following limitations and

identify possible areas for future study to help to address the gaps that we were unable to fill herein. First, because this was a cross-sectional study and results should be interpreted as correlational rather than causal, we obviously were unable to address whether zoning is exogenous or endogenous to active travel to work behaviors. In other words, what came first – the people or the zoning? (57) Unfortunately, given the enormity of the undertaking for this study, the project timeline, and our funding, we were unable to conduct a longitudinal study to examine whether code reform and active living-oriented zoning leads to higher rates of active travel to work (endogenous effect) or whether people who prefer to or are more inclined to engage in active travel to work purposefully select communities that are zoned and designed and that have the infrastructure to support active travel to work (exogenous effect). While future studies should definitely explore issues of endogeneity and exogeneity using alternative study designs, including longitudinal studies of communities over time, advocates, planners, and public health communities should find either conclusion to be positive because both appear to be associated with more people engaging in active travel. Second, our project and data collection timeline limited the policy lag between the zoning code effective dates and the active travel outcomes. As noted earlier, based on the information compiled, we can attest that the majority of communities' zoning codes were on-the-books well before our January 2010 cutoff; however, it was not humanly possible to determine which specific zoning elements were enacted at a given point in time (e.g., was MUZ permitted as of 2007). Future, longitudinal studies using the same sample frame will be well-positioned to monitor changes in zoning prospectively now that we have been able to compile a baseline of zoning provisions in effect as of 2010. This is one of the major contributions of our study. Additionally, we used the latest possible years of active travel data for our outcomes (in fact, the ACS 2010–2014 5-year estimates were only released in December 2015) to allow for as much of a lag as possible. Future studies should examine the association and, ideally, impact of these zoning provisions using later years of outcome data to allow for more time for full-scale policy implementation. In fact, that may account for some of the reasons why certain zoning markers were not statistically associated with the active travel behaviors – they simply may not have been on-the-books for a long enough period of time to have been fully implemented. Third, unfortunately we were unable to obtain zoning maps for the 3,914 municipalities included in this study. Had we been able to obtain the zoning maps, we would have been well-positioned to code for zoning overlays which apply to a portion of a jurisdiction (e.g., business district). As such, we were unable to assess the within-jurisdiction reach or coverage for each of the zoning measures. Although this would be a resource-intensive undertaking, it is something that researchers may want to test (albeit on a smaller scale) in future studies. Fourth, our sample only comprises municipal jurisdictions in counties or consolidated cities that cover 72.90% of the U.S. population. While our coverage is vast, including jurisdictions in 48 states and the District of Columbia, the findings from this study can only be generalized to the municipalities studied herein. However, the municipalities were located in 471 of the most populous counties and 2 independent cities and they ranged from very small (as few

as 500 people) to very large (millions of people), so we feel confident in the range of jurisdictions that were studied herein. Fifth, as noted earlier, while zoning is a key tool available to municipal planning and zoning officials that should not be overlooked, it is not the only tool at their disposal for effectuating changes to the built environment. Other such tools include but are not limited to capital improvement plans, impact fees, and design guidelines (38). Future studies should seek to examine these additional policy levers and their association with active travel to work. Finally, while we included a measure of community walkability using proven and reliable methods (36, 62), 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., trails, bike lanes, sidewalks, crosswalks, etc.). Future studies should compile such measures using regional, state, and local GIS data combined with objective assessments such as those obtained through direct observation or using innovative methods such as Google Street View photography (68, 69).

CONCLUSION

Despite the acknowledged limitations, this study offers new information and insight into one aspect of urban planning and land use design (i.e., zoning) that has rarely been studied on a magnitude of this scale nor have zoning provisions been associated with active travel to work behavior in communities nationwide. This study lends further credence to new urbanist theories that postulate that new urbanist zoning will create more pedestrian-friendly environments (or in our case, will be associated with more active travel to work involving walking and biking-related behaviors). And, importantly, the findings from this study support the calls by authoritative bodies such as the Surgeon General, the Institute of Medicine, and the National Physical Activity Plan for cross-sectoral collaborations and engagement in identifying and implementing strategies for facilitating adult PA, in this case active travel to work, which can lead to better population-level health outcomes.

AUTHOR CONTRIBUTIONS

JC conceptualized the study, led the writing and revision, oversaw the data collection, coding, and analysis, and was the

principal investigator on the study. JL conducted all of the data management and analysis, drafted the methods and analysis sections, prepared the tables, and contributed to revising and finalizing the manuscript. ET led all of the zoning policy collection and coding, conducted the literature review and helped to summarize the literature, and contributed to the revision and final manuscript preparation. LN helped to conceptualize the analytic methods, led the sample construction and oversaw the compilation and cleaning of the ACS data, and contributed to the manuscript drafting and final revision. SS contributed to the study conceptualization and framing, provided input into the analyses, and provide input and helped to draft the final version of the manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at <http://journal.frontiersin.org/article/10.3389/fpubh.2016.00071>

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