A New Urban Planning Code's Impact on Walking: The Residential Environments Project

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Objectives. We examined whether people moving into a housing development designed according to a state government livable neighborhoods subdivision code engage in more walking than do people who move to other types of developments.

Methods. In a natural experiment of 1813 people building homes in 73 new housing developments in Perth, Western Australia, we surveyed participants before and then 12 and 36 months after moving. We measured self-reported walking using the Neighborhood Physical Activity Questionnaire and collected perceptions of the environment and self-selection factors. We calculated objective measures of the built environment using a Geographic Information System.

Results. After relocation, participants in livable versus conventional developments had greater street connectivity, residential density, land use mix, and access to destinations and more positive perceptions of their neighborhood (all $P < .05$). However, there were no significant differences in walking over time by type of development ($P > .05$).

Conclusions. Implementation of the Livable Neighborhoods Guidelines produced more supportive environments; however, the level of intervention was insufficient to encourage more walking. Evaluations of new urban planning policies need to incorporate longer term follow-up to allow time for new neighborhoods to develop. (*Am J Public Health.* 2013;103:1219–1228. doi:10.2105/AJPH.2013.301230)

The impact of urban planning on health is well recognized[1,2]; however, recent trends in physical inactivity, sedentary lifestyles, and obesity have placed a significant focus on the need for better evidence to guide future urban planning and policy to support active living.[3] Furthermore, global population growth combined with an estimated 80% of people living in urban centers[4] highlights the increased need to build and regenerate cities so that they are health promoting. The recent United Nations General Assembly resolution on the prevention and control of noncommunicable diseases identified physical inactivity as 1 of the 4 leading risk factors for noncommunicable diseases.[5] Solutions recommended to combat physical inactivity included environmental changes related to urban planning, active transportation, parks, and recreational spaces.[5] Indeed, urban design policies and planning regulations that support and encourage walking are recommended across sectors, including public health, transportation, and planning.[6–8] Nevertheless, most studies underpinning recommendations to date are cross-sectional, and very few have examined the impact of environmental change on walking.[9,10]

There are few evaluations of policies designed to increase active living.[11–14] Studies of the impact of changes to community design and transportation infrastructure are difficult to design, and randomized controlled trials are not feasible. Thus, there have been calls for evaluations of natural experiments involving new transportation (e.g., congestion charging) or urban design (e.g., home zones) policies[11,15–18] with the aim of studying their impact on physical activity. A unique opportunity to evaluate a natural experiment of this type presented itself in 1998 when the Western Australian Department of Planning began trialing a new community design code aimed at increasing local walking and cycling.

The Livable Neighborhoods Guidelines[19] are essentially a local interpretation of new urbanism.[20,21] New urbanism (or neotraditional planning) evolved as a response to the conventional suburban sprawl thought responsible for a range of negative consequences, including car dependence, pollution, and traffic congestion. New urbanism combines elements of traditional housing design in walkable, mixed-use neighborhoods, as opposed to the low densities and curvilinear street layouts that characterize conventional suburbs.[22] The Livable Neighborhoods Guidelines incorporate 4 design elements aimed at increasing local walking and cycling: (1) a community design (e.g., mix of lot sizes, mixed-use planning), (2) a movement network (e.g., interconnected street networks, access to public transportation, traffic calming), (3) public parklands (e.g., balance between neighborhood parks and larger playing fields), and (4) lot layouts (e.g., to maximize surveillance of streets and parks, increased densities around public transportation and activity centers). We examined whether people moving into a housing development designed according to the Livable Neighborhoods Guidelines engaged in more walking than do people who move to other types of developments, and we examined differences in the built environment features of development types and changes in walking.

METHODS

The RESIDential Environments Project (RESIDE) commenced in 2003 and is a longitudinal natural experiment of 1813 people building homes in 73 new housing developments across metropolitan Perth, Western Australia. (Data available as a supplement to the online version of this article at http://www.ajph.org.)

The Western Australian Department of Planning classified 18 of the housing developments as livable (i.e., complying with most of the Livable Neighborhoods Guidelines), 11 as hybrid (i.e., complying with some but not all of the Livable Neighborhoods Guidelines), and 44 as conventional (i.e., not complying with any of the Livable Neighborhoods Guidelines).[23] We matched conventional developments to livable and hybrid developments using 3 criteria: stage of development (percentage vacant land), block value (which is an indicator of socioeconomic status), and proximity to the ocean.

Details of participant recruitment procedures have been reported elsewhere.[23] Briefly, the state water authority identified potential participants moving to each development and invited them to participate following the land transfer transaction. We applied the following eligibility criteria: English proficiency, aged 18 years and older, intention to relocate by December 2005, and willingness to complete a survey 3 times over 4 years. We recruited participants by telephone and randomly selected 1 person from each household.

We surveyed participants 3 times, each in the same season: before relocation (time point 1 [T1]; n = 1813) then approximately 12 months (time point 2 [T2]; n = 1467) and 36 months (time point 3 [T3]; n = 1230) after relocation. We derived the main results from the 1047 participants who provided complete data at all 3 time points (T1, T2, and T3).

Measures

Walking. Participants reported the duration of recreational and transportation walking undertaken in their neighborhood and outside their neighborhood (defined as a 15-min walk from their home) over a usual week using the Neighborhood Physical Activity Questionnaire,[24] which has been shown to have acceptable reliability.[24] We calculated changes in total weekly minutes of recreational, transportation, and total walking in the neighborhood from T1 to T2, T2 to T3, and T1 to T3.

Neighborhood environment perceptions. We derived perceptions of the neighborhood environment from the Neighborhood Environment and Walking Scale,[25] which included access to mixed-use services, street connectivity, cul-de-sacs present, traffic safety, traffic-slowing devices present, crime safety, and neighborhood aesthetics. Consistent with the Livable Neighborhoods Guidelines, we added an additional item: "On most streets in my local area there are footpaths on both sides of the streets." Participants also self-reported access to transportation, retail, recreation, and total destinations in the neighborhood (≤ 20-min walk from home).[25]

Objective measures of the neighborhood environment. At each time point, we generated objective built-environment measures using a Geographic Information System, and we included street connectivity,[26] residential density,[26] and land use mix.[27] We have developed separate measures of land use mix tailored to capture recreation and transportation-related walking and reported details of these measures elsewhere.[27] We defined the walkable service area by a 15-minute walk (1.6 km) street network buffer.[23] We calculated the count of different types of services (dry cleaner, post office, pharmacy, CD, DVD, and video store), convenience goods (deli, general store, supermarket, produce market, seafood market, gasoline station, other food market, shopping center), public open space destinations (park, sports field, beach), and public (bus and train) transportation stops in a 1600-meter service area of participants' homes.

Self-selection. At T1, participants rated the importance of 21 reasons that may have influenced their choice of new housing development.[23] Factor analysis revealed 5 underlying selection factors (streets are pedestrian and cycling friendly; access to services, jobs, or place of study; access to school; close to parks and recreational facilities; safe, diverse, and easy living community), accounting for 42% of the variance.[23] We used these variables to control for self-selection for choice of new neighborhood.

Statistical Analysis

We analyzed data using SAS version 9.3.[28] We used χ^2 analysis to examine the univariate association between development type and categorical variables: sociodemographic factors (gender, marital status, education level, children at home), self-selection factors, access to destinations (services, convenience goods, and public open space), and public transportation. We used the *F*-test from a general linear model to examine the univariate association between development type and continuous variables: age, transportation and recreational walking, perceptions of the built and social environment, and objective measures of street connectivity, residential density, and land use mix. We also used general linear models to examine the association between type of development and mean weekly minutes of neighborhood transportation, recreational and total walking for each time point (T1, T2, and T3), and change in mean weekly minutes of neighborhood transportation, recreational, and total walking between time points (T1 – T2, T2 – T3, and T1 – T3). We adjusted these models for baseline age; gender; education level; marital status; children at home; baseline minutes of recreational, transportation, or total walking; self-selection factors for choice of new neighborhood; and clustering within development.

RESULTS

Table 1 shows the characteristics at baseline (T1) before relocation of the 1047 participants who completed all 3 surveys. The mean age of participants was 42 years, 61% were female, 83% were married or in a de facto relationship, 72% had children (mean age = 7.6 years), and 23% had a bachelor's degree or higher level of education. Sociodemographic factors at baseline (T1) did not differ significantly across type of development.

We assessed reasons for the choice of new residential neighborhood as a source of potential self-selection bias (Table 1). A significantly greater proportion of participants moving into livable compared with hybrid or conventional developments rated the following features as important or very important (all $P < .05$): presence of pedestrian- and cycling-friendly streets; access to services, jobs, or places of study; closeness to parks and recreational facilities; and a safe, diverse, and easy living community.

The (unadjusted) mean-minutes per week of neighborhood, transportation, and recreational walking at each time point for those who completed all 3 time points (T1, T2, and T3) were very similar ($P > .05$) to those who only completed the first time point (T1) or completed 2 time points (T1 and T2). This indicates there was no attrition bias with respect to walking behavior for the group who completed all 3 time points (data available as a supplement to the online version of this article at http://www.ajph.org).

TABLE 1—Sociodemographic Characteristics and Self-Selection Factors at Baseline Before Relocation by Chosen Type of Development for New Residence: RESIDE study; Perth, Western Australia; 2003–2008

Variable	Livable Development (n = 299), % or Mean (SD)	Hybrid Development (n = 220), % or Mean (SD)	Conventional Development (n = 528), % or Mean (SD)	All Participants (n = 1047), % or Mean (SD)	P
Female	62.9	62.7	59.7	61.2	.578
Age, y	42.2 (12.2)	40.4 (11.8)	41.9 (11.6)	41.7 (11.8)	.206
Marital status					.221
Married or de facto	79.9	82.7	85.4	83.3	
Separated, divorced, or widowed	10.7	7.3	7.8	8.5	
Single	9.4	10.0	6.8	8.2	
Education level					.142
≤ secondary	32.4	40.9	39.0	37.5	
Trade, apprenticeship, or certificate	40.5	36.8	40.2	39.5	
≥ bachelor degree	27.1	22.3	20.8	22.9	
With children at home	71.2	69.1	74.4	72.4	.22
Age of children at home, y	7.8 (4.9)	6.5 (4.6)	7.8 (5.0)	7.6 (4.9)	.051
Self-selection factors[a]					
Streets are pedestrian and cycling friendly	72.6	68.6	64.0	67.4	.038
Access to services, jobs, or place of study	54.8	48.2	42.0	47.0	.002
Access to school	57.5	59.1	60.8	59.5	.648
Close to parks and recreational facilities	75.9	60.0	63.1	66.1	< .001
Safe, diverse, easy living community	86.0	85.5	78.4	82.0	.008

[a]Percentage perceive as important or very important.

Perceived Environment

Table 2 shows neighborhood perceptions at baseline (T1) and following relocation at 12 (T2) and 36 (T3) months. With 2 exceptions, there was little difference at baseline in any of the neighborhood characteristics by type of development to which participants were relocating at T2. A greater proportion of participants moving into livable than conventional developments agreed that their baseline neighborhood was safer from crime ($P = .04$) and had traffic-slowing devices present ($P = .015$).

However, at both 12 (T2) and 36 (T3) months, participants residing in livable developments had more positive perceptions of their new neighborhood's characteristics (Table 2) than did those residing in conventional developments. For example, a significantly greater proportion of participants in livable developments than in conventional developments agreed that they had access to mixed-use services, infrastructure and safety for walking, footpaths on both sides of the street, and an aesthetically pleasing neighborhood (all $P < .05$). Moreover, participants in livable developments reported access to more local retail (at both T2 and T3), recreational (at T3), transportation (at T3), and destinations overall (at T3) than did participants in conventional developments (all $P < .05$).

Objectively Measured Environment

In contrast to self-report measures, objectively measured baseline (T1) neighborhood characteristics varied between participants moving into different types of developments (Table 3). Greater street connectivity and residential density, but not land use mix, was evident at baseline for those moving into livable developments than for those moving into conventional developments ($P < .001$). Objective measures of the new neighborhoods at T2 and T3 showed that participants residing in livable developments had neighborhoods with significantly more street connectivity, residential density, and land use mix than did neighborhoods of those living in conventional developments (all $P < .001$). At T3, they also had neighborhoods with greater land use mix designed to encourage recreational walking (i.e., more public open space; $P < .001$).

Table 3 shows access to destinations by type of development. At 36 months postrelocation (T3), significantly more participants in livable developments had access to local services, convenience goods, and public open space and access to a greater number of local public transportation stops than did those in conventional developments ($P < .001$). However, notably at T3, 60% of participants in livable developments had no access to service destinations (e.g., dry cleaner, post office, pharmacy, and CD, DVD, and video store), and 71% had no access to destinations for daily living (e.g., general store, supermarket, produce market, seafood market, gasoline station, other food market, or shopping center) within 1600 meters of home. By contrast, only 4% had no access to public open space. Nevertheless, almost all participants of livable developments had access to 1 public transportation stop in their neighborhood. However, fewer than 1% had access to 2 public transportation stops. Across all development types, the majority of neighborhood public transportation stops were bus (≥ 99.3%) rather than train stops.

TABLE 2—Perceptions of Neighborhood Environment at Baseline and in New Neighborhood at 12 and 36 Months by Type of Development: RESIDE study; Perth, Western Australia; 2003–2008

Neighborhood Environment Perception	Livable Development (n = 299), % or Mean (SD)	Hybrid Development (n = 220), % or Mean (SD)	Conventional Development (n = 528), % or Mean (SD)	All Participants (n = 1047), % or Mean (SD)	Overall *P*	Livable vs Conventional *P*
Access to mixed-use services[a]						
T1	47.5	43.3	45.9	45.8	.642	.663
T2	29.8	12.9	21.6	22.1	< .001	.009
T3	41.5	23.0	25.8	29.7	< .001	< .001
Street connectivity[a]						
T1	33.2	33.3	34.0	33.7	.966	.812
T2	45.4	44.4	43.3	44.1	.833	.552
T3	45.8	50.9	44.4	46.2	.269	.712
Not many cul-de-sacs present[b]						
T1	28.1	30.6	25.8	27.4	.396	.463
T2	44.4	65.3	48.5	50.8	< .001	.265
T3	47.8	56.9	46.5	49.1	.032	.730
Infrastructure and safety for walking[a]						
T1	26.2	13.3	24.0	22.4	.001	.478
T2	40.3	14.2	21.1	25.1	< .001	< .001
T3	35.6	13.8	17.3	21.8	< .001	< .001
Footpaths present on both sides of road[b]						
T1	16.8	11.0	15.8	15.1	.158	.708
T2	30.5	15.1	9.9	16.9	< .001	< .001
T3	32.2	17.9	8.4	17.2	< .001	< .001
Traffic safety[a]						
T1	54.4	53.2	59.3	56.6	.201	.167
T2	75.5	69.7	72.6	72.8	.341	.367
T3	65.4	72.0	70.2	69.2	.221	.162
Traffic-slowing device present[b]						
T1	47.7	40.4	39.0	41.7	.047	.015
T2	54.4	51.4	52.1	52.6	.757	.530
T3	50.0	48.2	48.5	48.8	.892	.675
Crime safety[a]						
T1	54.0	45.4	46.6	48.5	.072	.040
T2	73.2	78.4	72.1	73.7	.191	.734
T3	67.1	72.5	68.8	69.1	.420	.613
Neighborhood aesthetics[a]						
T1	47.5	40.7	45.4	45.1	.305	.569
T2	70.2	68.5	62.5	66.0	.055	.026
T3	58.9	53.2	49.2	52.8	.029	.008
Transportation destinations[c]						
T1	6.4 (4.3)	6.0 (4.1)	6.2 (4.0)	6.2 (4.1)	.446	.472
T2	4.2 (3.8)	2.5 (2.4)	3.8 (3.5)	3.6 (3.5)	< .001	.133
T3	5.4 (4.3)	3.8 (3.2)	4.2 (3.7)	4.5 (3.8)	< .001	< .001
Retail destinations[c]						
T1	3.8 (3.2)	3.5 (3.0)	3.6 (3.1)	3.6 (3.1)	.354	.293
T2	2.2 (2.7)	0.8 (1.7)	1.8 (2.7)	1.7 (2.6)	< .001	.013
T3	2.9 (3.1)	1.5 (2.5)	2.0 (2.8)	2.2 (2.9)	< .001	< .001

Continued

TABLE 2—*Continued*

Recreation destinations[c]						
T1	2.5 (1.1)	2.3 (1.1)	2.4 (1.1)	2.4 (1.1)	.282	.590
T2	2.4 (1.0)	2.3 (0.9)	2.3 (0.9)	2.3 (1.0)	.534	.292
T3	2.7 (1.0)	2.4 (0.9)	2.3 (1.0)	2.4 (1.0)	< .001	< .001
Total destinations[c]						
T1	8.9 (4.7)	8.3 (4.5)	8.7 (4.4)	8.7 (4.5)	.314	.435
T2	6.5 (4.2)	4.8 (2.8)	6.1 (4.0)	6.0 (3.9)	< .001	.112
T3	8.1 (4.8)	6.2 (3.6)	6.5 (4.2)	6.9 (4.3)	< .001	< .001

Note. T1 = time point 1 (baseline); T2 = time point 2 (12 mo after moving); T3 = time point 3 (36 mo after moving).
[a]Multiple item scale (% with a mean > 3.5 on a 5-point Likert scale: strongly disagree to strongly agree).
[b]Single item (% agree or strongly agree).
[c]Mean (SD) number of destinations ≤ 20 min walk from home.

Changes in Walking Behavior

Table 4 shows the adjusted mean-minutes of walking undertaken by neighborhood type at each time point and the changes over time. Overall transportation walking decreased by 8 mean-minutes per week between T1 and T2 ($P<.001$) but increased by 7 mean-minutes per week between T2 and T3 ($P<.001$) for a net nonsignificant decrease of 1 mean-minute per week between T1 and T3 ($P=.507$). There were no significant differences in mean-minutes of transportation walking by development type at any time point or for any change across time points.

Overall, recreational walking increased by 17 mean-minutes per week between T1 and T2 ($P<.001$) and remained stable between T2 and T3 ($P=.516$) for a net significant increase of 20 mean-minutes per week between T1 and T3 ($P<.001$). Participants moving to hybrid developments reported significantly less recreational walking ($P=.022$) at T1 (before relocation); however, there were no other significant differences in recreational walking across the development types at any time point, and the mean differences did not vary over time.

Overall, total walking increased by 9 mean-minutes per week between T1 and T2 ($P<.01$) and increased further by 9 mean-minutes per week between T2 and T3 ($P>.05$) for a net significant increase of 18 mean-minutes per week between T1 and T3 ($P<.001$). All this gain was derived from increases in recreational walking following relocation. Recreational and total walking increased significantly for participants in livable and hybrid developments, but there was no significant intervention effect compared with participants in conventional developments because of higher baseline levels of walking in this group.

DISCUSSION

We observed small to modest significant differences in objective measures and perceptions of the neighborhood environment over time by type of development. Participants residing in livable developments had significantly greater street connectivity, residential density, and land use mix as well as access to a greater number of different types of destinations and more positive perceptions of their neighborhood than did those residing in conventional developments. However, after adjusting for baseline walking and sociodemographic, clustering, and self-selection factors, there were no significant differences in change in mean-minutes of neighborhood total, transportation, or recreational walking over time by type of development.

These findings suggest that the new housing developments designed according to the livable neighborhoods code generally supported walking more by providing more connectivity, residential density, and land use mix. This confirms that it is possible to use policy to create pedestrian-friendly environments. However, the level of intervention appeared insufficient to encourage significantly more walking in livable developments than in other developments. On average, participants living in livable and hybrid developments had a larger (but nonsignificant) increase in walking over time than did participants in conventional developments (26–27 vs 10 min/wk). This is likely because of the higher baseline levels of walking observed in participants moving to conventional developments. After relocating, walking levels of participants in livable and hybrid developments appeared to increase and become similar to those living in conventional developments. It is possible that the level of infrastructure observed in livable developments (e.g., public transportation stops, access to services and food outlets, or a combination of these features) did not reach a high enough threshold to cause walking levels to exceed those of residents of conventional developments. However, considering the early stage of development, the infrastructure continues to evolve and, over time, that threshold may be met. Nevertheless, little is known about the threshold of interventions required to bring about behavior change, and this warrants further investigation along with an assessment of the quality of those interventions.

Notably, the RESIDE study involves people currently living in a broadly scattered pattern across the whole of the Perth metropolitan area moving to new greenfield housing developments mostly located on the fringe of the Perth metropolitan area. On average, participants moved to lower residential density neighborhoods that had significantly less access to different types of destinations than did those of their baseline neighborhood. This decrease in neighborhood amenities after relocation may explain the observed decrease in transportation walking because residential density and access to destinations are consistently found to be associated with transportation walking.[7,29,30] Nevertheless, new neighborhoods take time to

TABLE 3—Connectivity, Residential Density, Land Use Mix, and Access to Types of Destinations and Public Transportation Across Time, by Type of Development: RESIDE study; Perth, Western Australia; 2003–2008

Variable	Livable Development (n = 299), Mean *z*-Score (SD) or %	Hybrid Development (n = 220), Mean *z*-Score (SD) or %	Conventional Development (n = 528), Mean *z*-Score (SD) or %	All Participants (n = 1047), Mean *z*-Score (SD) or %	Overall *P*	Livable vs Conventional *P*
Connectivity						
T1	0.283 (1.144)	−0.224 (0.835)	−0.067 (0.940)	0.000 (1.000)	< .001	< .001
T2	2.014 (1.858)	0.115 (0.680)	0.267 (0.965)	0.734 (1.486)	< .001	< .001
T3	2.371 (1.843)	0.572 (0.899)	0.571 (0.937)	1.085 (1.497)	< .001	< .001
Residential density						
T1	0.284 (1.471)	−0.175 (0.665)	−0.088 (0.715)	0.000 (1.000)	< .001	< .001
T2	0.093 (0.527)	−0.518 (0.472)	−0.445 (0.535)	−0.307 (0.578)	< .001	< .001
T3	0.227 (0.453)	−0.265 (0.296)	−0.167 (0.441)	−0.075 (0.462)	< .001	< .001
Land use mix (transportation walking)						
T1	0.041 (1.077)	0.032 (1.007)	−0.037 (0.951)	0.000 (1.000)	.488	.284
T2	−0.274 (0.953)	−0.704 (0.989)	−0.492 (0.821)	−0.474 (0.909)	< .001	.001
T3	−0.313 (0.682)	−1.201 (0.579)	−0.693 (0.668)	−0.691 (0.723)	< .001	< .001
Land use mix (recreational walking)						
T1	0.042 (1.072)	−0.012 (0.999)	−0.019 (0.959)	0.000 (1.000)	.691	.404
T2	−0.256 (0.966)	−0.432 (1.189)	−0.139 (0.827)	−0.234 (0.959)	< .001	.09
T3	−0.263 (0.657)	−0.846 (0.680)	−0.470 (0.702)	−0.490 (0.714)	< .001	< .001
			Types of services[a]			
T1						
0	29.1	35.9	35.2	33.6	.457	.242
1	27.4	22.7	26.3	25.9		
2	18.7	19.1	18.4	18.6		
≥ 3	24.7	22.3	20.1	21.9		
T2						
0	61.2	92.3	56.3	65.2	< .001	< .001
1	6.0	5.9	24.6	15.4		
2	16.7	0.0	10.6	10.1		
≥ 3	16.1	1.8	8.5	9.3		
T3						
0	59.9	92.3	57.2	65.3	< .001	< .001
1	9.4	0.5	23.3	14.5		
2	16.1	5.5	11.2	11.4		
≥ 3	14.7	1.8	8.3	8.8		
			Types of convenience goods[b]			
T1						
0	25.8	25.0	23.1	24.3	.016	.019
1	16.1	24.5	24.8	22.3		
2	13.7	18.6	14.8	15.3		
≥ 3	44.5	31.8	37.3	38.2		
T2						
0	59.5	94.5	66.3	70.3	< .001	.144
1	18.1	1.8	13.6	12.4		
2	8.4	3.2	9.1	7.6		
≥ 3	14.0	0.5	11.0	9.6		

Continued

TABLE 3—*Continued*

T3						
0	70.9	84.5	55.7	66.1	< .001	< .001
1	11.0	12.3	21.6	16.6		
2	2.0	2.7	12.1	7.3		
≥ 3	16.1	0.5	10.6	10.0		
Types of public open space[c]						
T1						
0	0.3	1.8	1.1	1.1	.05	.072
1	76.9	84.1	81.8	80.9		
≥ 2	22.7	14.1	17.0	18.1		
T2						
0	4.7	4.5	2.5	3.5	< .001	< .001
1	75.6	93.6	89.6	86.4		
≥ 2	19.7	1.8	8.0	10.0		
T3						
0	4.0	4.5	2.1	3.2	< .001	< .001
1	75.9	93.6	90.0	86.7		
≥ 2	20.1	1.8	8.0	10.1		
Public transportation stops[d]						
T1						
0	1.0	1.8	0.9	1.1	.883	.988
1	89.6	88.6	90.0	89.6		
2	9.4	9.5	9.1	9.3		
T2						
0	0.0	0.0	4.0	2.0	< .001	< .001
1	99.3	100.0	96.0	97.8		
2	0.7	0.0	0.0	0.2		
T3						
0	0.0	0.0	4.4	2.2	< .001	< .001
1	99.3	100.0	95.6	97.6		
2	0.7	0.0	0.0	0.2		

Note. T1 = time point 1 (baseline); T2 = time point 2 (12 mo after moving); T3 = time point 3 (36 mo after moving). We derived the z-score from standardized values.
[a]Count of different types of services: dry cleaner, post office, pharmacy, CD, DVD, or video store within 1600 m.
[b]Count of different types of convenience goods: deli, general store, supermarket, produce market, seafood market, gasoline station, other food market, shopping center within 1600 m.
[c]Count of different types of public open space: park, sports field, beach access within 1600 m.
[d]Number of bus stops and railway stations within 1600 m.

develop, and these results highlight that for evaluations of new urban planning policies, longer term follow-up is paramount.

Another plausible explanation for the nonsignificant changes in minutes of walking over time between development types is that the Livable Neighborhoods Guidelines have not been fully implemented. Fewer than 1% of participants in livable developments had access to 2 public transportation stops in their neighborhood, and 60% to 70% had no access to service or convenience goods destinations within 1600 meters of their home. This suggests that key aspects of the Livable Neighborhoods Guidelines[19] related to community design (mixed-use planning) and the movement network (access to public transportation) are yet to be realized. By contrast, irrespective of development type, all participants had good access to public open space, and this may explain why overall recreational walking increased after relocation and why there were no observed significant differences in recreational walking over time by type of development. Since the 1950s, the Western Australia state government has mandated that 10% of land in new housing developments be allocated to public open space,[31] which likely explains these findings.

Overall, these results indicate that people's behavior changes in response to a changing environment, highlighting the importance of planning policies on health. However, comprehensive evaluations of the level of implementation are required to study the impact of new planning codes. This would provide information on the extent to which the policy has been implemented as intended, also known as intervention fidelity.[32] Importantly, it is recommended that future natural experiments incorporate

TABLE 4—Adjusted Mean-Minutes and Differences for Neighborhood Transportation, Recreational, and Total Walking per Week, by Type of Development: RESIDE study; Perth, Western Australia; 2003–2008

Variable	Livable Development (n = 299), Mean (SE)	Hybrid Development (n = 220), Mean (SE)	Conventional Development (n = 528), Mean (SE)	All Participants (n = 1047), Mean (SE)	Overall *P*	Livable vs Conventional *P*
Transportation walking, min						
Mean						
T1	25.5 (3.2)	22.7 (3.6)	28.1 (2.4)	26.2 (1.7)	.453	.509
T2	15.2 (2.9)	17.0 (3.4)	19.6 (2.2)	17.9 (1.5)	.473	.234
T3	25.6 (4.1)	20.9 (4.8)	25.7 (3.1)	24.8 (2.1)	.677	.984
Mean difference						
T1 – T2	–10.8 (2.8)***	–8.4 (3.2)	–7.0 (2.1)***	–8.3 (1.5)***	.564	.285
T2 – T3	9.1 (3.8)**	3.6 (4.3)	7.0 (2.8)	6.9 (2.0)***	.634	.643
T1 – T3	–0.4 (4.0)	–4.3 (4.6)	–0.9 (3.0)	–1.4 (2.1)	.78	.92
Recreational walking, min						
Mean						
T1	65.9 (5.6)	56.9 (6.4)	77.3 (4.2)	69.6 (2.9)	.022	.104
T2	84.5 (6.2)	79.8 (7.2)	91.4 (4.7)	87.0 (3.3)	.359	.38
T3	95.1 (9.1)	94.5 (10.5)	86.2 (6.5)	89.9 (4.6)	.66	.429
Mean difference						
T1 – T2	16.6 (5.7)**	16.0 (6.6)***	18.1 (4.2)***	17.3 (3.0)***	.955	.828
T2 – T3	9.3 (8.8)	10.2 (10.1)	–2.3 (6.2)	2.9 (4.5)	.415	.279
T1 – T3	26.3 (8.8)***	30.9 (10.2)*	12.6 (6.2)	19.6 (4.6)***	.222	.21
Total, min						
Mean						
T1	91.4 (6.8)	79.6 (7.9)	105.4 (5.1)	95.8 (3.6)	.017	.102
T2	99.8 (7.0)	96.8 (8.1)	111.1 (5.2)	104.9 (3.7)	.233	.198
T3	121.2 (10.2)	114.1 (11.8)	111.6 (7.4)	114.5 (5.3)	.75	.449
Mean difference						
T1 – T2	5.7 (6.4)	7.6 (7.4)*	11.2 (4.8)	9.0 (3.4)**	.780	.5
T2 – T3	19.3 (9.5)*	13.2 (11.0)	3.8 (6.8)	9.6 (5.0)	.401	.19
T1 – T3	27.4 (9.3)***	26.2 (10.8)	10.5 (6.8)	18.1 (4.9)***	.251	.147

Note. T1 = time point 1 (baseline); T2 = time point 2 (12 mo after moving); T3 = time point 3 (36 mo after moving); T1 – T2 = change between time points 1 and 2; T2 – T3 = change between time points 2 and 3; T1 – T3 = change between time points 1 and 3. Adjusted for baseline age; gender; education level; marital status; children at home; baseline minutes of recreational, transportation, or total walking; self-selection factors for choice of new neighborhood; and clustering.
*$P \le .05$; **$P \le .01$; ***$P \le .001$.

a comprehensive process evaluation to assess the dose of intervention implemented.[33,34]

There are few examples of the evaluation of policies and their effect on walking behavior, although the need for such studies has been identified.[13,35] Evaluation of these policies can provide an early warning system if the policy is ineffective, is not being optimized,[18,35] or produces unintended negative consequences. Importantly, it can provide information on when to tighten policy because either the policy is not being implemented as intended or it is taking longer than expected to be implemented. However, at the time we undertook this evaluation the Livable Neighborhoods Guidelines were voluntary guidelines and not a formal mandated policy. Thus, features of the code that were harder and more costly to implement (e.g., land use mix) may not have been fully incorporated or, as we have identified, not incorporated within the time frame of this study. The results of this study provide preliminary evidence suggesting that some but not all planning design features of the Livable Neighborhoods Guidelines were implemented by the 36-month follow-up. However, the policy's impact on residents' walking behavior is less clear. Although study participants' walking behaviors changed in response to a changing environment, the level of intervention in livable developments was insufficient to increase residents' behavior more than did other developments. Thus, longer term follow-up is warranted of both participants and their neighborhoods to assess the extent to which all features of the livable neighborhoods code are implemented and the code's impact on walking behaviors. This would assist in strengthening the Livable Neighborhoods Guidelines before they are mandated as statewide urban design planning policy.

This study highlights the potential value of incentives to reduce time frames for the delivery of infrastructure in new neighborhoods. For example, the Livable Neighborhoods Guidelines provides developers with a 2% dispensation on the amount of public open space required in new areas if they agree to develop and maintain the public open space during the establishment phase of the development. Because of the time taken for businesses to develop in greenfield developments, it may be possible to incentivize business development. These incentives might include reduced land tax or council rates and temporary buildings to house supermarkets and essential social infrastructure such as schools and child care centers. Incentives such as these would facilitate and support the early establishment of local services, businesses selling goods for daily living, and local employment opportunities, which are critical features of planning codes designed to encourage local walking and cycling.

Limitations

As we have identified, time is required for all neighborhood features to be implemented and long-term follow-up of residents is essential. Although randomized controlled trials are the gold standard for intervention research, randomization is rarely possible for evaluations of built environment interventions. Best practice study designs for natural experiments are now being proposed to strengthen the evidence from such studies and permit their use in systematic reviews.[36] Our findings are limited to new homebuyers moving into urban fringe greenfield developments. This was unavoidable because the RESIDE study involved evaluating a new subdivision design code. There is inevitable dropout of participants in longitudinal studies. However, we found no evidence of attrition bias in comparisons of walking behavior because of participant dropout. Finally, the limitations of self-report physical activity measures are well documented.[37]

Conclusions

The introduction of new urban and transportation policies provides opportunities for natural experiments evaluating their impact on health-related outcomes. Our findings suggest that implementation of the Livable Neighborhoods Guidelines has had a more positive effect on the neighborhood environment of residents in livable developments than on that of residents in conventional developments; however, over 3 years it is possible that the level of intervention was insufficient to significantly affect walking behavior. Our results highlight that future natural experiments of urban planning policies need to incorporate long-term follow-up to allow time for new neighborhoods to develop and should consider process evaluation to monitor policy implementation and fidelity. ■

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Contributors

H. Christian, M. Knuiman, F. Bull, A. Timperio, S. Foster, N. Middleton, and B. Giles-Corti conceptualized and designed the RESIDE study. H. Christian led the writing, drafting, and revising of the article. H. Christian, S. Foster, N. Middleton, and B. Giles-Corti acquired the data. M. Divitini analyzed the data. All authors interpreted findings, reviewed and provided feedback on drafts of the article, and approved the final version.

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Human Participant Protection

The University of Western Australia's human research ethics committee (No. RA/4/1/479) provided ethics approval for this study.

References

1. Snow J. *On the Mode of Communication of Cholera.* London, UK: John Churchill; 1855.

2. Corburn J. Reconnecting with our roots. American urban planning and public health in the twenty-first century. *Urban Aff Rev.* 2007;42(5):688–713.

3. *Interventions on Diet and Physical Activity: What Works: Summary Report.* Geneva, Switzerland: World Health Organization; 2009.

4. United Nations Population Fund. *State of World Population 2011.* New York, NY: UNFPA; 2012.

5. United Nations. Sixty-Seventh Session Political Declaration of the High Level Meeting of the General Assembly on the Prevention and Control of Non-communicable Diseases. 2011. Available at: http://www.un.org/ga/search/view_doc.asp?symbol=A/66/L.1. Accessed October, 7, 2011.

6. Kopelman P, Jebb SA, Butland B. Executive summary: foresight 'tackling obesities: future choices' project. *Obes Rev.* 2007;8(suppl 1):Svi–Six.

7. Transportation Research Board. *Does the Built Environment Influence Physical Activity? Examining the Evidence.* Washington, DC: Transportation Research Board; 2005.

8. Planning Institute of Australia. *Heart Foundation. Healthy Spaces and Places. Towards a National Planning Guide.* Melbourne, Australia: Planning Institute of Australia; 2008.

9. Krizek KJ. Residential relocation and changes in urban travel: does neighborhood-scale urban form matter? *J Am Plann Assoc.* 2003;69(3):265–281.

10. Wells NM, Yang Y. Neighborhood design and walking. A quasi-experimental longitudinal study. *Am J Prev Med.* 2008;34(4):313–319.

11. Ogilvie D, Mitchell R, Mutrie N, Petticrew M, Platt S. Evaluating health effects of transport interventions: methodologic case study. *Am J Prev Med.* 2006;31(2):118–126.

12. Rodriguez D, Khattak A, Evenson K. Can new urbanism encourage physical activity? *J Am Plann Assoc.* 2006;72(1):43–54.

13. Boarnet MG, Anderson CL, Day K, McMillan T, Alfonzo M. Evaluation of the California Safe Routes to School legislation: urban form changes and children's active transportation to school. *Am J Prev Med.* 2005;28(suppl 2):S134–S140.

14. Ogilvie D, Bull F, Powell J, et al. An applied ecological framework for evaluating infrastructure to promote walking and cycling: the iConnect study. *Am J Public Health.* 2011;101(3):473–481.

15. Egan M, Petticrew M, Ogilvie D, Hamilton V. New roads and human health: a systematic review. *Am J Public Health.* 2003;93(9):1463–1471.

16. Egan M, Petticrew M, Ogilvie D, Hamilton V, Drever F. "Profits before people"? A systematic review of the health and safety impacts of privatising public utilities and industries in developed countries. *J Epidemiol Community Health.* 2007;61(10):862–870.

17. Sallis JF, Story M, Lou D. Study designs and analytic strategies for environmental and policy research on

obesity, physical activity, and diet: recommendations from a meeting of experts. *Am J Prev Med.* 2009;36(suppl 2): S72–S77.

18. Story M, Giles-Corti B, Yaroch AL, et al. Work group IV: future directions for measures of the food and physical activity environments. *Am J Prev Med.* 2009;36 (suppl 4):S182–S188.

19. Western Australian Planning Commission. *Liveable Neighbourhoods.* Perth, Australia: Western Australian Planning Commission; 2000.

20. Congress for the New Urbanism. *Congress for the New Urbanism Charter Awards.* Chicago, IL: Congress for the New Urbanism; 2001. Available at: http://www.cnu.org/awards/recipients#2001. Accessed June, 24, 2011.

21. Congress for the New Urbanism. *Congress for the New Urbanism Strategic Plan 2012–2017.* Chicago, IL: Congress for the New Urbanism; 2012.

22. Duany A, Plater-Zyberk E, Speck J. *Suburban Nation: The Rise of Sprawl and the Decline of the American Dream.* New York, NY: North Point Press; 2000.

23. Giles-Corti B, Knuiman M, Timperio A, et al. Evaluation of the implementation of a state government community design policy aimed at increasing local walking: design issues and baseline results from RESIDE, Perth, Western Australia. *Prev Med.* 2008;46(1):46–54.

24. Giles-Corti B, Timperio A, Cutt H, et al. Development of a reliable measure of walking within and outside the local neighborhood: RESIDE's Neighborhood Physical Activity Questionnaire. *Prev Med.* 2006;42(6):455–459.

25. Cerin E, Saelens BE, Sallis JF, Frank LD. Neighborhood Environment Walkability Scale: validity and development of a short form. *Med Sci Sports Exerc.* 2006;38 (9):1682–1691.

26. Frank L, Schmid T, Sallis J, Chapman J, Saleens B. Linking objectively measured physical activity with objectively measured urban form: findings from SMARTRAQ. *Am J Prev Med.* 2005;28(2S2):117–125.

27. Christian HE, Bull FC, Middleton NJ, et al. How important is the land use mix measure in understanding walking behaviour? Results from the RESIDE study. *Int J Behav Nutr Phys Act.* 2011;8:55.

28. *SAS* [computer program]. Version 9.3. Cary, NC: SAS Institute; 2010.

29. Owen N, Humpel N, Leslie E, Bauman A, Sallis JF. Understanding environmental influences on walking: review and research agenda. *Am J Prev Med.* 2004;27 (1):67–76.

30. Saelens BE, Handy SL. Built environment correlates of walking: a review. *Med Sci Sports Exerc.* 2008;40(7): S550–S566.

31. Stephenson G, Hepburn J. *Plan for the Metropolitan Region Perth and Fremantle.* Perth, Australia: Government Printing Office; 1955.

32. Falconer R, Newman P, Giles-Corti B. Is practice aligned with the principles? Implementing new urbanism in Perth, Western Australia. *Transp Policy.* 2010;17(5):287–294.

33. Hooper P. *The Rise and Sprawl of the Australian Dream? An Evaluation of the Implementation and Impacts of the "Liveable Neighbourhoods Community Design Code"* [PhD dissertation]. Perth, Australia: University of Western Australia; 2012.

34. Hooper P. *Quantifying Policy Implementation: An Evaluation of the "Liveable Neighbourhoods Community Design Code."* Melbourne, Australia: International Symposium of Behavioral Nutrition and Physical Activity; 2011.

35. Ogilvie D, Foster CE, Rothnie H, et al. Interventions to promote walking: systematic review. *BMJ.* 2007;334 (7605):1204.

36. Ogilvie D, Bull F, Cooper A, et al. Evaluating the travel, physical activity and carbon impacts of a 'natural experiment' in the provision of new walking and cycling infrastructure: methods for the core module of the iConnect study. *BMJ open.* 2012;2(1):e000694.

37. McCormack G, Giles-Corti B, Lange A, Smith T, Martin K, Pikora T. An update of recent evidence of the relationship between objective and self-report measures of the physical environment and physical activity behaviors. *J Sci Med Sport.* 2004;7(suppl 1):S81–S92.