New Walking and Cycling Routes and Increased Physical Activity: One- and 2-Year Findings From the UK iConnect Study

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Objectives. We evaluated the effects of providing new high-quality, traffic-free routes for walking and cycling on overall levels of walking, cycling, and physical activity.

Methods. 1796 adult residents in 3 UK municipalities completed postal questionnaires at baseline (2010) and 1-year follow-up (2011), after the construction of the new infrastructure. 1465 adults completed questionnaires at baseline and 2-year follow-up (2012). Transport network distance from home to infrastructure defined intervention exposure and provided a basis for controlled comparisons.

Results. Living nearer the infrastructure did not predict changes in activity levels at 1-year follow-up but did predict increases in activity at 2 years relative to those living farther away (15.3 additional minutes/week walking and cycling per km nearer; 12.5 additional minutes/week of total physical activity). The effects were larger among participants with no car.

Conclusions. These new local routes may mainly have displaced walking or cycling trips in the short term but generated new trips in the longer term, particularly among those unable to access more distant destinations by car. These findings support the potential for walking and cycling infrastructure to promote physical activity. (*Am J Public Health.* 2014;104:e38–e46. doi:10.2105/AJPH.2014.302059)

Walking and cycling are important sources of everyday activity[1,2] and are independently associated with a wide range of health benefits.[3–6] The potential magnitude of such benefits may be particularly large in settings such as the United Kingdom, where most people are insufficiently active for health (only 5% of adults, as assessed using accelerometry[7]) and where cycling in particular is rare (accounting for 2% of journeys[8]). It is widely recognized that a supportive built environment may be needed to promote walking and cycling and to achieve an enduring increase in activity at the population level.[9–12] Nevertheless, multiple recent reviews[10,13–19] have highlighted the paucity of rigorous studies evaluating the effects of new walking and cycling infrastructure such as segregated cycle routes or traffic-free bridges.

Drawing on such controlled, longitudinal studies as do exist, recent systematic reviews have provided limited evidence as to whether infrastructural improvements increase walking or cycling.[18–20] Five studies (from Denmark, England, the Netherlands, and the United States) reported increases in cycling after the implementation of fairly substantial infrastructure improvements such as building cycle parking, extending networks of on- and off-road cycle routes, or modifying junctions to create advance stop lanes for cyclists.[21–25] Interpretation is complicated, however, by the fact that these infrastructural modifications were sometimes accompanied by other cycling initiatives (e.g., media campaigns, cycle training, or community-based events).[22–24] Likewise, in many walking interventions the infrastructural improvements were small relative to other intervention components. For example, 3 studies (from Australia, Belgium, and the United States) evaluated whole-community walking programs that, among many other things, improved signage, made minor repairs to footpaths, or cleaned up walking trails.[26–28] One reported no overall change in population walking levels,[26] and a second reported modest increases.[27] The third focused on promoting walking trails and found that trail use increased but overall walking levels did not.[28] Another US study reported significant increases in walking and cycling around a newly built urban trail[29] but could not determine whether this reflected new walking and cycling or simply trips displaced from elsewhere. Finally, a recent Australian study reported that moving home to an area with greater access to local recreational or transport-related destinations predicted increases in walking[30] but not cycling.[31]

In summary, the evidence has suggested that infrastructural interventions may increase walking or cycling when delivered at high doses, but at lower doses may be used without necessarily increasing total activity. In addition, few studies have examined whether any effects are observed equally across different population groups, and very few have examined equity impacts with respect to any characteristic other than gender.[18,19,32] Among those that have, 1 Australian study found a trend toward a larger increase in activity among women than men,[26] 1 English study found comparable changes across all socioeconomic groups,[23] and 1 English and 1 US study found some suggestion of larger increases among socioeconomically disadvantaged groups.[24,28] None of these 4 studies included formal tests for interactions.

THE NATURAL EXPERIMENT

Led by the sustainable transport charity Sustrans, the Connect2 initiative was established with the intention of building or improving walking and cycling routes at 79 sites across the United Kingdom. Applications for projects were put forward by local authorities or community groups and selected on the basis of criteria that included engineering feasibility, strong leadership, the availability of local matched funding, the likely usefulness of the project to local people, and a desire to create a range of schemes covering a wide range of places and circumstances. Each Connect2 site consists of 1 flagship engineering project (the core Connect2 project) and improvements to signed, on- and off-road feeder cycle routes leading into that flagship project (the greater Connect2 project). Projects are tailored to individual sites, but all embody a desire to create new routes for "everyday, local journeys by foot or by bike."[33]

Programs such as Connect2 represent natural experiments: events, policies, or interventions not designed for research purposes but that may nevertheless provide valuable research opportunities.[34] The independent iConnect research consortium (http://www.iconnect.ac.uk) was established to evaluate the travel, physical activity, and carbon impacts of Connect2.[35,36] Previous iConnect research has reported that levels of use and awareness of the new Connect2 infrastructure increased markedly among residents living closer to the infrastructure relative to residents living farther away.[37] Proximity therefore appeared to provide a promising way to operationalize different degrees of intervention exposure among local residents and so to provide the type of variation in intervention exposure status that is necessary to make controlled comparisons in natural experimental studies.[34]

The aim of this study was to evaluate the effects of the Connect2 intervention on overall walking, cycling, and physical activity levels. Our primary hypothesis was that the higher exposure to the intervention among adults living progressively nearer to the infrastructure would be translated into increased overall activity levels relative to adults living farther away. As further tests for causality, we tested the secondary hypotheses that any effects of proximity would be (1) confined to Connect2 users and (2) driven by changes in the types of activities most commonly reported on Connect2. Finally, we investigated whether any associations were moderated by individual or household characteristics, such that some groups benefited more from the intervention than others.

METHODS

As previously described in detail,[35,36] we selected 3 Connect2 projects for detailed study according to criteria including implementation timetable, likelihood of measurable population impact, and heterogeneity of overall mix of sites. These study sites were Cardiff, where a traffic-free bridge was built over Cardiff Bay; Kenilworth, where a traffic-free bridge was built over a busy trunk road; and Southampton, where an informal riverside footpath was turned into a boardwalk (Supplementary File, part 1, including Figures A–D; available as a supplement to this article at http://www.ajph.org). None of these projects had been implemented during the baseline survey in April 2010. At 1-year follow-up, most feeder routes had been upgraded, and the core projects had opened in Southampton and Cardiff in July 2010. At 2-year follow-up, almost all feeder routes were complete, and the core Kenilworth project had opened in September 2011. There was a formal opening event at each of these 3 sites, plus a modest amount of additional promotion of the new infrastructure.

In April 2010, survey packs were mailed to 22 500 adults randomly selected using the edited electoral register (which covers around 60% of adults aged 18 years and older[38]) and living within 5 kilometers by road of the core Connect2 projects.[35] The 3516 individuals returning the pack (16% response rate) were mailed follow-up surveys in April 2011 and April 2012. After excluding a small number of individuals who had moved or had unreliable physical activity data (change of ≥ 900 minutes/week), the 1-year follow-up study population consisted of 1796 participants (51% retention, 8% of the population originally approached) and the 2-year study population consisted of 1465 participants (42% retention, 7% of the population approached: see Figure E for flowchart, available as a supplement to this article at http://www.ajph.org). Comparisons with local and national data suggested that participants included a smaller proportion of young adults than the general population (7% younger than 30 years in the 2-year sample vs 26% of adults locally) and were also somewhat healthier, better educated, and less likely to have children. Otherwise, the study population appeared to be broadly representative in its demographic, socioeconomic, and travel- and activity-related characteristics (Table A, available as a supplement to this article at http://www.ajph.org).[37,39]

Exposure to the Intervention

We prespecified the primary measure of intervention exposure to be proximity to the Connect2 infrastructure,[35] with less-exposed people living farther from Connect2 acting as a comparison group for the more-exposed people living closer to Connect2. We operationalized proximity as the distance from the weighted population centroid of the participant's home postal code to the nearest access point to a completed section of the greater Connect2 project. Residential unit postal codes typically contain approximately 50 people.

We calculated distance in ArcGIS 9 (Esri, Redlands, CA) using the Ordnance Survey's integrated transport network and urban path layers, which include the road network plus traffic-free or informal paths. Findings were very similar in sensitivity analyses using proximity to the core (flagship) Connect2 project rather than the greater Connect2 project.

Baseline Characteristics and Use of the Intervention

In the baseline survey, participants reported their demographic, socioeconomic, and health characteristics (Table 1). The follow-up surveys then described the local Connect2 project and asked participants whether they used it (yes, no).

Those who did were asked whether they (1) walked or (2) cycled on Connect2 for recreation, health, or fitness or for 5 separate journey purposes (commuting for work, travel for education, travel in the course of business, shopping or personal business, and social or leisure activities). The full questionnaire is available online at http://bmjopen.bmj.com/content/2/1/e000694/suppl/DC1.

Walking, Cycling, and Physical Activity Outcome Measures

We assessed past-week walking and cycling for transport using a 7-day recall instrument covering the 5 journey purposes previously listed.[35] For each journey purpose, participants reported the total travel time in 7 transport modes, including walking and cycling. We

TABLE 1—Participants' Characteristics at Baseline in the 1- and 2-Year Follow-Up Samples: Connect2, Cardiff, Kenilworth, and Southampton, United Kingdom; April 2010–April 2012

Variable	1-Year Sample, No. (%)	2-Year Sample, No. (%)
Geographic		
Site		
Southampton	506 (28.2)	408 (27.9)
Cardiff	579 (32.2)	473 (32.3)
Kenilworth	711 (39.6)	584 (39.9)
Proximity of home to greater Connect2, km		
≥ 4.00	173 (9.6)	141 (9.6)
3.00–3.99	132 (7.4)	103 (7.0)
2.00–2.99	286 (15.9)	222 (15.2)
1.00–1.99	613 (34.1)	474 (32.4)
< 1.00	592 (33.0)	525 (35.8)
Demographic		
Sex		
Female	979 (54.5)	831 (56.7)
Male	817 (45.5)	634 (43.3)
Age at baseline, y		
18–34	233 (13.0)	141 (9.7)
35–49	372 (20.8)	291 (19.9)
50–64	590 (32.9)	519 (35.5)
65–89	596 (33.3)	510 (34.9)
Ethnicity[a]		
White	1723 (96.4)	1417 (96.9)
Non-White	64 (3.6)	45 (3.1)
Any child < 16 y in the house		
No	1501 (83.6)	1236 (84.4)
Yes	294 (16.4)	229 (15.6)
Socioeconomic and Car/Bicycle Access		
Educational level		
Tertiary or equivalent	693 (38.8)	576 (39.5)
Secondary school[b]	607 (34.0)	479 (32.8)
None or other	485 (27.2)	405 (27.7)
Annual household income, £		
> 40 000	569 (34.1)	439 (32.1)
20 001–40 000	540 (32.4)	461 (33.7)
≤ 20 000	560 (33.6)	469 (34.3)
Employment status		
Working	916 (51.0)	720 (49.2)
Student	46 (2.6)	24 (1.6)
Retired	687 (38.3)	589 (40.3)
Other	147 (8.2)	130 (8.9)
Car in household		
No	237 (13.2)	203 (13.9)
Yes	1558 (86.8)	1257 (86.1)
Adult bicycle in household		
No	741 (44.4)	603 (44.6)
Yes	929 (55.6)	748 (55.4)

Continued

measured past-week recreational physical activity using an adapted version of the short form of the International Physical Activity Questionnaire[40] in which we modified the question stems to ask participants to report only recreational activity.[35] Participants reported total past-week time spent walking for recreation, cycling for recreation, in moderate-intensity leisure-time physical activity, and in vigorous-intensity leisure-time physical activity.

We derived our primary outcome, total past-week walking and cycling, by summing the total time walking or cycling for transport or recreation from across these 2 instruments. To this we added time spent in other moderate- or vigorous-intensity activity to create our secondary outcome, total past-week physical activity. We have previously shown that the test–retest reliability and convergent validity with respect to accelerometry of our modified short International Physical Activity Questionnaire are comparable to those of other questionnaires of similar length, including the unmodified short International Physical Activity Questionnaire.[41]

Statistical Analyses

We examined intervention effects by calculating within-participant changes in past-week time spent (1) walking and cycling and (2) in all physical activity (histograms of the distribution of changes are shown in Figure F, available as a supplement to this article at http://www.ajph.org). To assess whether any overall effects were driven by particular activity subdomains, we also calculated changes separately for walking for transport, walking for recreation, cycling for transport, and cycling for recreation. We used linear regression to examine how proximity to the infrastructure predicted changes in these outcomes, entering proximity as a linear term (all $P\text{s} > .08$ for linearity). We initially adjusted models for age, sex, and site and then additionally adjusted for ethnicity, having a child younger than 16 years, education, income, employment status, having a car in the household, weight status, general health, and long-term illness (all measured at baseline and categorized as in Table 1). Adjusted models also included the baseline measure of the activity outcome in question. We excluded individuals whose total reported physical activity changed by 900 minutes per week or

TABLE 1—*Continued*

Health		
Weight		
Normal or underweight	849 (49.7)	683 (49.0)
Overweight	625 (36.6)	515 (37.0)
Obese	236 (13.8)	195 (14.0)
General health		
Excellent–good	1393 (78.6)	1137 (78.5)
Fair–poor	380 (21.4)	312 (21.5)
Long-term illness or disability that limits daily activity		
No	1261 (74.8)	1021 (74.0)
Yes	426 (25.3)	359 (26.0)
Time spent walking or cycling in past week, min		
None	284 (15.8)	229 (15.6)
1–149	464 (25.8)	376 (25.7)
150–299	408 (22.7)	344 (23.5)
300–449	263 (14.6)	211 (14.4)
≥ 450	377 (21.0)	305 (20.8)

Note. All demographic, socioeconomic, health, and activity variables were self-reported by participants, including height and weight to calculate weight status. Numbers add to fewer than the total number of participants for some variables because of missing data.
[a]The non-White group combined Black, South Asian, mixed race, and "other" ethnic groups.
[b]British A Levels, General Certificate of Secondary Education, or equivalent.

more (n = 53 in 2011, n = 45 in 2012) on the basis that such extreme outliers might reflect self-report measurement error (e.g., misreporting 15 minutes as 15 hours). In a sensitivity analysis, we also excluded those whose activity for a given outcome changed by 600 minutes per week or more.

Guided by the iConnect evaluation framework,[36] we tested for interactions with 9 characteristics: site (Southampton, Cardiff, Kenilworth), sex (male, female), age (as a continuous variable), highest education level (tertiary or equivalent, below tertiary), employment status (currently working, not working), annual household income (> £40 000, £20 001–£40 000, ≤ £20 000), and the presence in the household of any child younger than 16 years (yes, no), any car (yes, no), or any adult bicycle (yes, no). We tested for interactions only in those models in which infrastructure proximity was significantly associated with the primary outcome because we wanted to minimize multiple testing and had no reason to expect interactions whereby some groups decreased their physical activity as a result of the intervention.

Missing data ranged from 0% to 1.2% across exposure and outcome variables and from 0% to 7.8% among covariates. We imputed these data using multiple imputations by chained equations (5 imputations) under an assumption of missing at random. We used robust standard errors to allow for the very small degree of clustering between participants in the same Lower Super Output Area (administrative areas with an average population of 1500). We conducted statistical analyses using Stata version 11 (StataCorp, College Station, TX).

RESULTS

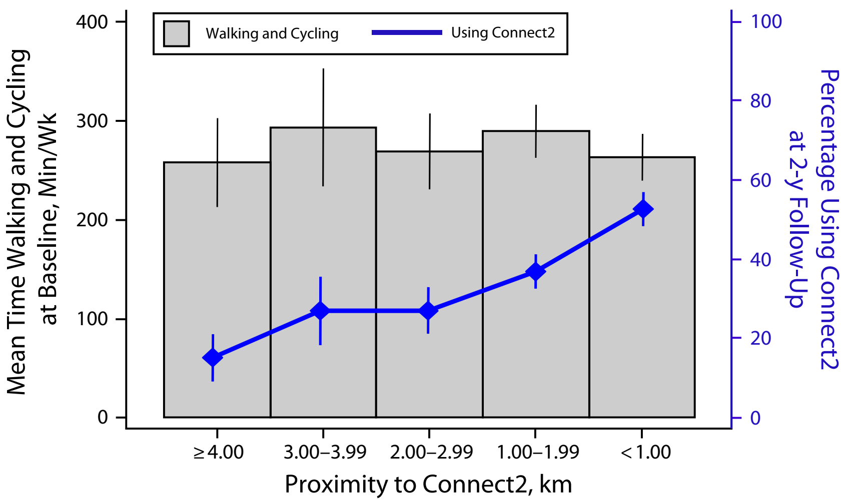
The 1- and 2-year follow-up samples had very similar characteristics (Table 1), and we found no evidence that infrastructure proximity was associated with retention at follow-up or with any individual or household characteristic (all *P*s > .05; most *P*s > .2). Proximity to Connect2 was likewise not associated with preintervention activity levels but was strongly and progressively associated with greater use of Connect2 (Figure 1).

This combination of properties confirmed the suitability of proximity as our (prespecified) primary exposure for controlled comparisons. By contrast, baseline activity levels strongly predicted subsequent Connect2 use and post hoc power calculations also suggested that contrasts by use were underpowered (Table B, Figure G, available as a supplement to this article at http://www.ajph.org). We therefore focus on contrasts with respect to proximity, presenting contrasts by use in the supplementary material (Tables D–E, available as a supplement to this article at http://www.ajph.org).

Effects on Overall Walking, Cycling, and Physical Activity

In total, 32% of participants reported using Connect2 at 1-year follow-up and 38% reported using it at 2-year follow-up. Patterns of use were very similar at both time points, with walking for recreation being by far the most commonly reported use and cycling for transport the least commonly reported (Table 2).

Across the 2 years of follow-up, mean levels of walking and cycling remained relatively stable in our sample as a whole (change of +4 minutes/week at 1-year follow-up and +0 minutes/week at 2-year follow-up, relative to baseline), but mean levels of other moderate- to vigorous-intensity physical activity declined (–16 and –24 minutes/week, respectively, relative to baseline; see Table B, available as a supplement to this article at http://www.ajph.org). As for our key question of whether proximity to Connect2 predicted changes in the activity levels of those living nearer the intervention versus those living farther away, we found little or no evidence of this for any activity outcome at 1-year follow-up. This remained true after excluding the Kenilworth site, where the core project was incomplete at 1-year follow-up (adjusted effect = 5.4 minutes/week per km closer to the intervention; 95% confidence interval [CI] = –11.4, 22.3, for our primary outcome). At 2-year follow-up, by contrast, individuals living nearer Connect2 did report significant increases their past-week walking and cycling relative to those living farther away, with an effect of 15.3 minutes per week per kilometer closer to the intervention (95% CI = 6.5, 24.2) after adjusting for baseline demographic, socioeconomic, and health characteristics plus walking and cycling time at baseline (*P* < .001; Table 3). This indicates that, on average, those living 1 kilometer from the new infrastructure increased their walking



Note. Whiskers indicate 95% confidence intervals. The findings were very similar when we repeated the analysis for the 1-year sample and for Connect2 use at 1-year follow-up.

FIGURE 1—Association between proximity to Connect2 and (1) past-week walking and cycling at baseline and (2) Connect2 use at 2-year follow-up: Cardiff, Kenilworth, and Southampton, United Kingdom; April 2010–April 2012.

and cycling by 15.3 minutes per week relative to those 2 kilometer away, and by 15.3 × 3 = 45.9 minutes per week more than those 4 kilometers away. In the context of stable levels of walking and cycling in the overall sample, this reflected some absolute increase in activity among those living nearest the infrastructure and some absolute decrease among those living farther away (see Table B, available as a supplement to this article at http://www.ajph.org).

Proximity was also associated with a comparable increase in past-week total physical activity (adjusted effect = 12.5 minutes/week per km closer to the intervention; 95% CI = 1.9, 23.1) and not associated with any change in moderate- to vigorous-intensity activity excluding walking and cycling (adjusted effect = 0.1 minutes/week; 95% CI = –6.3, 6.5). We thus found no evidence that the gains in walking and cycling were offset by reductions in other forms of activity.

Consistent with a causal interpretation, we observed 2-year effects of proximity only among those who reported actually using the infrastructure (adjusted effect = 30.0 minutes/week; 95% CI = 3.5, 55.5 among Connect2 users vs adjusted effect = 7.4 minutes/week; 95% CI = –5.3, 20.1 among nonusers for total walking and cycling). Associations with activity subdomains were also consistent with a causal interpretation, with effects seen for the 3 more common Connect2 uses (walking for recreation, cycling for recreation, and walking for transport) but not the rarest use (cycling for transport; Tables 2 and 3). The contribution of walking for transport was, however, greater than expected given levels of Connect2 use for this purpose. Interestingly, this was also the only activity subdomain showing a near-significant association with proximity at 1-year follow-up.

TABLE 2—Proportion of Study Population Reporting Using Connect2 for Different Purposes: Cardiff, Kenilworth, and Southampton, United Kingdom; April 2010–April 2012

Variable	Full Sample, %		Connect2 Users, %	
	1-Year Follow-Up	2-Year Follow-Up	1-Year Follow-Up	2-Year Follow-Up
Use for any purpose	32	38	100	100
Walking for recreation	27	33	84	85
Cycling for recreation	12	15	37	39
Walking for transport	11	12	34	31
Cycling for transport	5	7	16	18

Note. The sample sizes were n = 1776 in the 1-year sample and n = 1449 in the 2-year sample (at both timepoints, 1.1% of participants had missing data on Connect2 use and were excluded).

Sensitivity Analyses

The 2-year effects of proximity remained significant but were considerably attenuated after excluding 65 individuals whose total walking and cycling changed by 600 minutes per week or more (Table 3). The overall effect was thus driven to an important extent by people living near Connect2 and reporting very large increases in walking or cycling. For example, among individuals living within 1 kilometer of Connect2, 22 increased their total walking and cycling by 600 minutes per week or more and 5 decreased by 600 minutes per week or more. Among individuals living more than 1 kilometer away, these numbers were more evenly balanced (18 vs 21).

The people who substantially increased their activity were spread relatively evenly across the 3 sites, and walking for recreation was the single largest contributor to the overall change (accounting for 51% of the difference). All types of Connect2 use were much more common among those who reported an increase of 600 minutes per week or more than among who did not (60% vs 34% for walking on Connect2, 31% vs 16% for cycling; both *Ps* < .01 for difference).

Effect Modification by Car Ownership

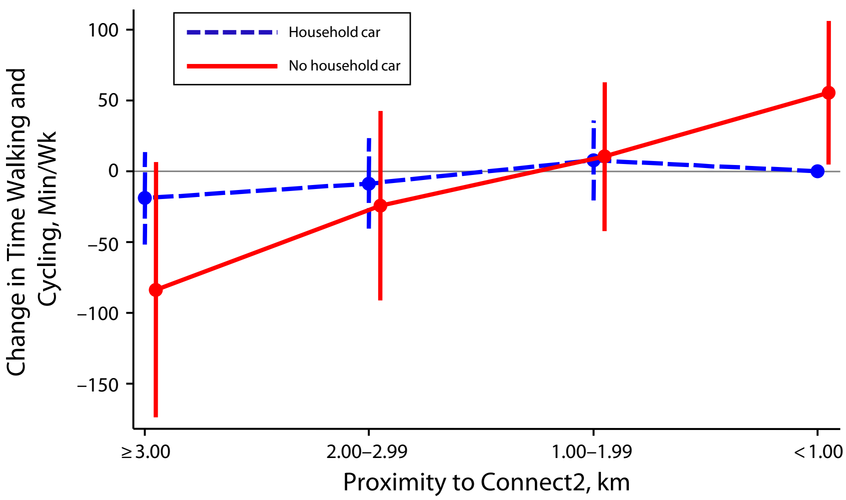
We found no evidence that the effect of Connect2 proximity on walking and cycling at 2-year follow-up was moderated by site, sex, age, education, employment, income, having a child, or bicycle access (all *Ps* > .2). We did find, however, strong evidence that the effect was stronger if there was no car in the participants' household (adjusted effect = 46.8 minutes/week per km closer to Connect2; 95% CI = 21.6, 72.1) than if the household had access to a car (adjusted effect = 10.2 minutes/week; 95% CI = 0.3, 20.1; *P* = .007 for interaction; Figure 2).

TABLE 3—Association Between Proximity to Connect2 and Change in Walking, Cycling, and Total Physical Activity at 1- and 2-Year Follow-Up: Parameter Estimates and 95% Confidence Intervals for Change in Minutes per Week in the Activity Outcome per Kilometer Closer to Connect2: Cardiff, Kenilworth, and Southampton, United Kingdom; April 2010–April 2012

	1-y Change, b (95% CI)			2-y Change, b (95% CI)		
Outcome behavior	Minimally Adjusted for Age, Sex, and Site	Adjusted for Baseline Characteristics[a]	Sensitivity Analysis (Adjusted, Excluding Outliers)[b]	Minimally Adjusted for Age, Sex, and Site	Adjusted for Baseline Characteristics[a]	Sensitivity Analysis (Adjusted, Excluding Outliers)[b]
Main outcomes						
Total walking and cycling	4.2 (–4.6, 13.0)	4.6 (–4.2, 13.4)	0.9 (–6.8, 8.5)	15.9 (6.4, 25.4)	15.3 (6.5, 24.2)	9.2 (0.6, 17.9)
Total physical activity	3.6 (–7.5, 14.6)	4.3 (–5.9, 14.5)	1.2 (–6.6, 9.0)	13.4 (2.0, 24.8)	12.5 (1.9, 23.1)	10.5 (1.8, 19.2)
Activity subdomains						
Walking for recreation	0.0 (–7.0, 7.1)	–1.1 (–8.1, 5.8)	–2.7 (–9.2, 3.9)	7.5 (–1.3, 16.3)	6.8 (–0.6, 14.1)	2.3 (–4.6, 9.2)
Cycling for recreation	–1.0 (–4.0, 2.1)	–0.7 (–3.4, 2.0)	–0.9 (–3.5, 1.8)	4.4 (0.9, 7.8)	2.5 (0.1, 4.9)	1.8 (–0.3, 3.8)
Walking for transport	5.8 (–0.6, 12.2)	5.8 (–0.7, 12.3)	3.0 (–2.9, 8.8)	8.0 (2.1, 13.8)	8.8 (2.8, 14.8)	6.8 (1.8, 11.8)
Cycling for transport	0.3 (–2.2, 2.7)	0.4 (–1.9, 2.7)	–0.7 (–2.4, 1.0)	0.2 (–2.1, 2.4)	–0.2 (–2.2, 1.8)	–1.1 (–2.7, 0.6)

Note. CI = confidence interval.
[a]Adjusted for site, baseline demographic, socioeconomic, and health characteristics plus baseline levels of the activity in question.
[b]Adjusted as in previous column and excluding those with a change score ≥ 600 min/wk.

The strength of this interaction was attenuated slightly but remained significant ($P = .03$) after excluding individuals whose total walking and cycling changed by 600 minutes per week or more. This interaction was also observed with respect to total past-week physical activity (adjusted $P = .007$) and with respect to the 3 activity subdomains showing main-effect associations with proximity (all $.03 \le P < .09$: stratified results in Table C, available as a supplement to this article at http://www.ajph.org).



Note. Whiskers indicate 95% confidence intervals. *P* = .007 for interaction.

FIGURE 2—Interaction between car ownership and proximity to Connect2 in predicting change in total walking and cycling at 2-year follow-up: Cardiff, Kenilworth, and Southampton, United Kingdom; April 2010–April 2012.

DISCUSSION

Newly constructed walking and cycling routes were well used at both 1- and 2-year follow-up, particularly among those living nearby. In this study, our primary hypothesis was that walking, cycling, and total physical activity would increase more among those living nearer the infrastructure relative to those living farther away. We found that infrastructure proximity did not predict increased activity at 1-year follow-up, but it did predict net increases in walking, cycling, and total physical activity at 2 years. On average, at 2-year follow-up residents living 1 kilometer from the new infrastructure reported a 45-minute increase in walking and cycling per week relative to those living 4 kilometers away. Although the effect estimates come with fairly wide confidence intervals, the point estimates are similar to those for the most effective interventions of any kind to promote walking.[18] Moreover, individuals living near the infrastructure did not compensate for their increased walking and cycling by reducing their participation in other types of physical activity. Consistent with a causal interpretation, the effects were confined to those who used the infrastructure and were largely driven by increases in the more commonly reported types of infrastructure use. These changes were partly driven by a few individuals who substantially increased their activity levels, but even after excluding these outliers there remained a significant and nontrivial net increase of 27 minutes per week for those living 1 kilometer versus 4 kilometers away. The effect of proximity on activity levels was stronger among individuals with no car in their household.

Strengths and Limitations

Key strengths of this study include its cohort design, population-based sampling, use of 3 separate intervention sites, and use of controlled comparisons within the local resident populations. By contrast, most previous studies have used repeat cross-sectional designs,[21–23,26,29,42] sampled only infrastructure users,[29] included only a single intervention site,[21,22,25–29] or used comparison groups that were not comparable at baseline.[26,42] Among other advantages, our study allowed verification of the appropriateness of the primary exposure by demonstrating that Connect2 proximity was not associated with baseline characteristics but did predict subsequent infrastructure use. We hope this may encourage other natural experimental studies to consider this approach as a means of enhancing rigor by ascertaining individual-level exposures[10] and generating appropriate comparison groups.[34] Another important strength of this study is its measurement of total levels of walking, cycling, and physical activity. By contrast, previous studies in this field have used outcomes such as modal share[21,22,24,25] that are less directly translatable into health benefits.

Nevertheless, this study had several important limitations. Although we sought to minimize measurement error by using 7-day recall instruments appropriate to the specific outcomes under investigation, the outcome measures were limited in being self-reported. Partly for this reason, perhaps, they had high standard deviations, and this reduced statistical power. The nonsignificant, positive point estimates observed at 1-year follow-up are therefore consistent with small genuine effects that we lacked power to detect, and they lend some support to arguments in favor of using more accurate and precise (but potentially more expensive) objective measures of activity in future intervention studies.[43] A second key limitation is the potential for selection bias: given the relatively low response rate, the study population cannot be assumed to be representative. We piloted our recruitment process carefully within the resources available,[38] but more expensive options such as door-to-door recruitment for surveys administered by interviewers could be considered for future studies. Yet although our sample was older than the general population, participants otherwise appeared fairly similar in their demographic, socioeconomic, and travel-related characteristics.[37,39] Moreover, we know of no reason to expect differential biases with respect to intervention proximity, the primary exposure. A third limitation is that it was not possible to blind participants to their exposure status, although we did endeavor to limit their exposure to information regarding the key hypothesis under consideration in our study.[35] One way of minimizing this problem in the future would be to nest evaluation studies within established studies (e.g., national birth cohort studies), which collect data on a much wider range of exposures and outcomes.[34]

Study Implications and Directions for Future Research

Interventions such as Connect2 may trigger many different patterns of use, including displacing walking and cycling trips that would have been made anyway on different routes, prompting motor vehicle users to shift some of their existing trips to walking and cycling, or generating new walking or cycling trips when otherwise no trip would have been made at all. Our null 1-year findings suggest that Connect2 use may initially often have involved route substitution—that is, changing where users walked or cycled but not necessarily how much overall. This interpretation is consistent with the fact that, as described elsewhere,[37] baseline activity showed a strong and highly specific association with subsequent Connect2 use (i.e., baseline levels of walking for transport specifically predicted walking for transport on Connect2). It is also consistent with some previous studies reporting no evidence of changes in overall activity levels, despite changes in awareness or use of specific walking trails.[26,28,44,45] By contrast, at 2-year follow-up we found that those living nearer the intervention had increased their activity levels relative to those farther away. This discrepancy between the time points is in some ways surprising, given that the levels, patterns, and correlates of infrastructure use were very similar.[37] However, interventions such as Connect2 occur within complex systems,[46] and effects may emerge only gradually through feedback loops related to habit formation.[36] It may be that over time, some Connect2 users came to recognize opportunities to make new trips or participate in additional recreational activities.

Particularly for recreational walking and cycling, the overall positive effects at 2 years were partly driven by a few outlier individuals reporting large activity increases. This could reflect either a few individuals consistently doing much more recreational activity or else a larger number sometimes doing much more (e.g., occasionally using Connect2 during a long weekend walk). Given the high proportion of participants reporting using Connect2 for recreation, we believe the latter interpretation is more plausible. By contrast, excluding outliers had less effect on the association between proximity and walking for transport, and this subdomain also contributed disproportionately to the overall intervention effects. This suggests that those who walk for transport on Connect2 do so more consistently and, on average, for longer per week than those who walk for recreation. As for the stronger intervention effects among non–car owners, they may reflect the particular importance of local walking and cycling routes for a group that may find it harder to access more distant destinations. Connect2 may thus have helped to mitigate one form of transport poverty,[47] namely the disabling effect of having no car in a car-dominated society.[48–50] However, this finding also suggests that the extra walking and cycling trips generated by Connect2 did not usually represent a modal shift away from motorized travel. This is consistent with our demonstration that proximity to Connect2 did not have any detectable impact on estimated transport carbon emissions at 1- or 2-year follow-up.[51]

Conclusions

Our results provide evidence that improved, high-quality, traffic-free routes for walking and cycling may help to increase overall physical activity levels in the local population and thereby contribute to the primary prevention of a range of noncommunicable diseases. This lends support to recent calls to increase the provision of such routes in local communities.[1,15,16] We believe the findings from our case study sites may in principle be generalizable to other, similar projects planned within and beyond the Connect2 program. Further evaluation is, however, required as the scale of implementation increases from local routes to more comprehensive improvements across wider areas; it is plausible that intervention effects will become even stronger as more destinations become connected by a high-quality network that constitutes a higher dose of intervention. Through such improvements to infrastructure (and its supporting evidence base), we hope that communities will progressively realize the substantial health and environmental benefits of making walking and cycling a convenient, safe, and attractive everyday activity. ■

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Contributors

D. Ogilvie led the design of the study, and D. Ogilvie and S. Sahlqvist contributed to the design and piloting of the data collection instruments. A. Goodman led the data analysis and interpretation for this article, in collaboration with D. Ogilvie and S. Sahlqvist. A. Goodman drafted the article, with D. Ogilvie and S. Sahlqvist revising it for important intellectual content. All authors approved the final version of this article.

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Human Participant Protection

The University of Southampton Research Ethics Committee granted ethical approval (CEE200809-15).

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