# The Effect of Light Rail Transit on Body Mass Index and Physical Activity

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**Background:** The built environment can constrain or facilitate physical activity. Most studies of the health consequences of the built environment face problems of selection bias associated with confounding effects of residential choice and transportation decisions.

**Purpose:** To examine the cross-sectional associations between objective and perceived measures of the built environment; BMI; obesity (BMI>30 kg/m$^2$); and meeting weekly recommended physical activity (RPA) levels through walking and vigorous exercise. To assess the effect of using light rail transit (LRT) system on BMI, obesity, and weekly RPA levels.

**Methods:** Data were collected on individuals before (July 2006–February 2007) and after (March 2008–July 2008) completion of an LRT system in Charlotte NC. BMI, obesity, and physical activity levels were calculated for a comparison of these factors pre- and post-LRT construction. A propensity score weighting approach adjusted for differences in baseline characteristics among LRT and non-LRT users. Data were analyzed in 2009.

**Results:** More-positive perceptions of one's neighborhood at baseline were associated with a −0.36 ($p<0.05$) lower BMI; 15% lower odds (95% CI=0.77, 0.94) of obesity; 9% higher odds (95% CI=0.99, 1.20) of meeting weekly RPA through walking; and 11% higher odds (95% CI=1.01, 1.22) of meeting RPA levels of vigorous exercise. The use of LRT to commute to work was associated with an average −1.18 reduction in BMI ($p<0.05$) and an 81% reduced odds (95% CI=0.04, 0.92) of becoming obese over time.

**Conclusions:** The results of this study suggest that improving neighborhood environments and increasing the public's use of LRT systems could provide improvements in health outcomes for millions of individuals.

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## Introduction

Physical inactivity in the U.S. has serious implications for obesity and its attendant comorbidities.[1–5] Obesity can result from an excess of caloric intake versus energy exerted through routine physical activity, so even small reductions in physical activity can put individuals at risk. Post–World War II zoning laws that encouraged separating commercial, residential, and recreational land uses have promoted automobile usage over walking, biking, and public transit.[6] Research has linked the associated effects of zoning laws on urban sprawl, unitary land uses, and less walkable street networks to a lack of physical activity in the population.[7,8]

The health benefits of moderate and vigorous physical activity are clear.[9–13] Less-vigorous forms of physical activity are more likely to be sustained over time, making it easier to meet exercise goals through the promotion of walking as a basic change in one's daily routine.[14–16] Increasing the availability of public transit systems is one among a number of modifications to the built environment that offers some promise in increasing opportunities for physical activity and reducing the prevalence of obesity.[17–20] The use of public transit is associated with an

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increased likelihood that individuals will meet physical activity recommendations through walking.[21–24] Cities in the U.S. are investing in alternate forms of public transit, including the design and expansion of light rail transit systems.[25] A number of studies indicate that people who walk to and from public transit obtain significantly more daily physical activity than those who do not. Minorities and lower-income individuals, groups at the greatest risk for obesity, are also more likely to receive the health benefits of walking to transit.[26]

Assessing the relationships between measures of the built environment and physical activity and obesity is important in order to better inform public policies regarding the effect that adaptations in the built environment can have on promoting more physically active lifestyles.[27–35] Selection bias, however, presents a problem with cross-sectional studies investigating the link between the built environment and health outcomes.[36,37] Individuals with less economic resources may take public transit out of necessity, but they may maintain otherwise unhealthy lifestyles. On the other hand, individuals more predisposed to being physically active may choose to live in urban environments more suitably designed for healthy lifestyles.[38]

The current study had two primary aims. The first aim was to examine the cross-sectional associations among objective and perceived measures of the built environment, physical activity, and obesity. And the second aim was to rely on a natural experiment of the built environment induced by the introduction of a new light rail transit (LRT) line to assess the impact of transit use on obesity and physical activity levels. The use of a natural experiment and propensity score matching were intended to reduce the effects of selection bias endemic in cross-sectional studies of the effects of the built environment on health outcomes. It is hypothesized that individuals who use the LRT system will experience a significant increase over time in meeting recommended daily physical activity levels and reductions in BMI compared to similarly situated individuals who do not use LRT.

## Methods

Data for a pre–post longitudinal study were collected on a sample of individual household members living in Charlotte NC near the site of the current South Corridor Light Rail (LRT) line. Subjects were selected through phone sampling based on census tract addresses that were within a 1-mile radius of the LRT line before it started operating. The catchment area was selected because it was within a reasonable distance from the LRT line and because the area reflected the most heavily traveled area for commuters living in Charlotte's southern region and working in the downtown central business district.[39] The survey sample frame included household telephone numbers in the GENESYS database associated with the chosen catchment area (Figure 1). To randomize selection into the survey, a single adult member of each household was selected based on the individual with the most recent birthday.

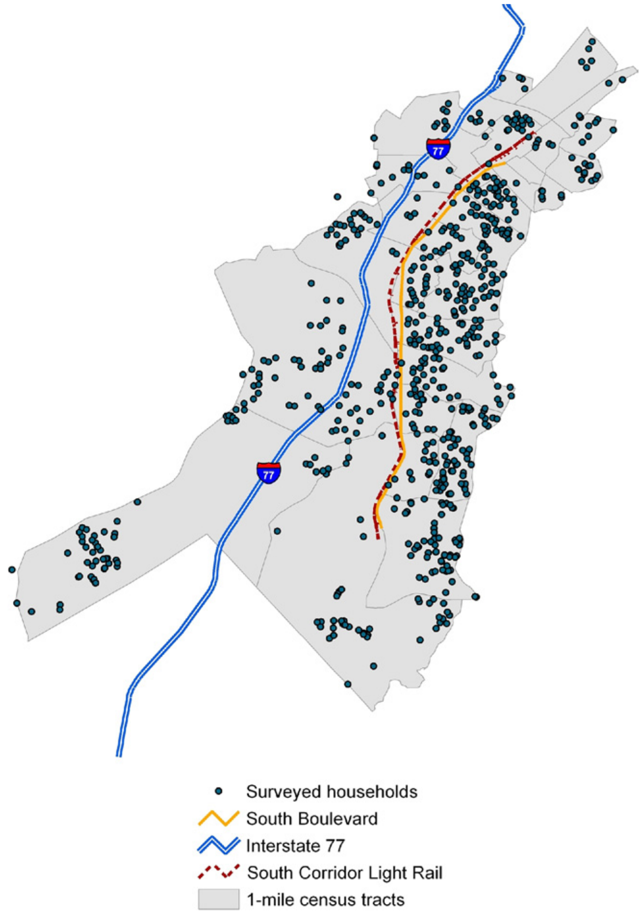


**Figure 1.** Study area and home locations of survey respondents ($n$=839)

Approximately 839 adult household members were recruited to participate in a baseline survey 8–14 months before (July 2006–February 2007) the opening (pre) of the LRT (45% response rate). A total of 498 respondents (60%) were re-interviewed 6–8 months (March 2008–July 2008) after the LRT system became operational (post). Only subjects who maintained continuous residency in the catchment area were re-interviewed. The main observable cause of attrition from the baseline sample was for renters who moved out of the catchment area. The overall response rate at follow-up was 87%, with only 3% ($n$=20) refusals.

A pre–post intervention design was used to assess the effect of LRT use on BMI, obesity, and meeting weekly recommended levels of physical activity. The pre–post design was used to control for residential location choice. A propensity score analysis was used to reduce the effects of choice to use LRT, in comparing changes in BMI, obesity, and physical activity levels among residents who used the LRT after it opened to similarly situated residents who did not use the LRT system.

### Data and Measures

The two primary data sources used were a telephone survey and objective measures of the physical environment taken from Info

USA, the U.S. GDC Park Landmarks, and Census Tiger/Line Files. Home and work addresses of survey respondents were geocoded into Census TIGER/line road files.[40] The telephone survey assessed perceptions of the physical and social environment of neighborhoods, social demographic factors, and respondents' daily travel and exercise patterns through a modified version of the CDC's Behavioral Risk Factor Surveillance System and the National Household Travel Survey.[41,42]

**BMI** was calculated in kg/m$^2$ using self-reported height and weight. Respondents with a BMI ≥30 were coded as obese.

Physical activity was assessed using a modified version of the International Physical Activity Questionnaire (IPAQ).[43] The IPAQ was modified to measure vigorous exercise and moderate physical activity through walking. Vigorous activity was measured by asking respondents how many days a week they typically do vigorous physical exercise that makes them breathe much harder than normal and includes heavy lifting, digging, aerobics, or fast bicycling. Moderate physical activity was measured by asking respondents to indicate how many days a week they typically *walk* for at least 10 minutes at a time and the usual length (in minutes) of their walks. Physical activity was analyzed according to two dichotomous outcomes measuring whether the respondent met the American College of Sports Medicine and the American Heart Association recommended weekly physical activity (RPA) levels through vigorous exercise or moderate physical activity through walking (vigorous activity 3 times a week, ≥20 minutes a time; or walking 5 times a week, ≥30 minutes a time).[14]

Perceptions of neighborhood social and physical environments were measured according to eight questions about the respondents' surrounding neighborhood. Respondents were asked to indicate the level of problems (*a big problem*, *a small problem*, *not a problem*) that exist within a 15-minute walk from their home.[44] The list of these measures included concerns about litter/trash in the streets; kids hanging out on the streets without adult supervision; vacant housing or storefronts; poorly maintained property; access to parks or recreational facilities (reverse coded); traffic; drinking in public; and crime. Principal components analysis was used to reduce these items to a single composite scale (Cronbach's alpha=0.75)[45] that measures the perceived social and physical environmental problems in each neighborhood. A higher score signified a more negative perception.

Objective measures of the physical environment were created by geocoding subject addresses into ArcView, version 9.2,[40] and creating land-use measures shown to be related to exercise and health outcomes. A variable for residential density was computed by using the number of household units per a square-mile buffer from the respondent's address according to Census Tiger/Line road files. A second land-use variable measured whether or not a respondent's household had a recreational park within a half-mile radius.[46] A third land-use variable measured the density of establishments that sell food (grocery, convenience, and restaurants) and alcohol within a half-mile buffer of respondents' households. These data were geocoded from an address file obtained from Info USA.[47] The food and alcohol outlet density measure was converted into SD units (*z*-scores) in the models.

Public transit use at baseline was assessed through a question that asked respondents how often they took public transportation (bus or rail). Public transportation use was dichotomized to whether or not the respondent took public transportation on a regular basis (at least once a week).

Plans to use LRT were measured at baseline prior to exposure because it was recognized that the use of LRT transit may be associated with individuals planning to use it in the future. A dichotomous indicator was created representing whether or not someone planned on using the LRT when it opened in the future to reduce this source of selection bias.

LRT usage was assessed during the follow-up (exposure) interview through a question that asked respondents if they used LRT to commute to work on a daily basis. A dichotomous indicator was created representing whether or not the respondent used LRT to commute to work.

## Statistical Methods

Two sets of outcome analyses are presented. First, an assessment was made of the cross-sectional effect of individual and neighborhood environmental factors on the average BMI, odds of obesity, and odds that respondents meet recommended physical activity levels (RPA) at baseline, prior to LRT exposure. Multivariate regression models were estimated on the outcome variables, adjusting for age; gender; race (black versus other); employment status; education level; rent versus own residence; distance to work; perceptions of neighborhood environments; access to parks; density of food and alcohol establishments; household density per square mile; and use of public transit on a weekly basis. Second, the effect of LRT on changes in BMI, obesity, and physical activity levels were examined.

The present study mitigated the potential influence of selection bias in the analysis with a pre–post design and a propensity score model that equalized the treatment and control groups on baseline variables that predicted the use of LRT in the future. A nonparametric logistic regression model was used to estimate the propensity scores, which allows for nonlinear relationships and up to three-way interactions and maximizes the comparability between treatment and control subjects.[48] Treatment subjects were defined as those who indicated using LRT on a daily basis to commute to work during the follow-up interview. Approximately 5.2% ($n$=26) of the longitudinal sample ($n$=498) used LRT to commute to work daily. Control subjects were defined as those who were also working (full-time or part-time) but did not use LRT to commute to work ($n$=275). Control subjects were then reweighted so that the distribution of the baseline covariates matched individuals who used LRT. The weights were such that non-LRT users who had features similar to those of LRT users had larger propensity scores and larger weights.

Table 1 shows how after weighting non-LRT users to look like LRT users, the two groups are more statistically comparable on nine baseline pre-exposure (T1) covariates. The two groups were substantively different on six of the nine baseline covariates before weighting, but differ on only two covariates (race and plans to use LRT in future) after weighting on the propensity score. The two groups were statistically comparable on T1 measures of BMI, obesity, and meeting walking and vigorous RPA.

After equalizing LRT users and control subjects on baseline confounders, the effect of LRT on change in BMI, obesity, and RPA was estimated. The outcome measures were modeled as basic change scores as expressed in the following form:

$$Y_{2i} = \beta_0 + \beta_1 Y_{1i} + \beta_2 T_i + X_i{}' \beta.$$

$Y_{2i}$ denotes the outcome for the participant $i$ at time 2 (post-LRT exposure); $Y_{1i}$ denotes participant $i$'s outcome at time 1 (pre-LRT exposure); $T_i$ is a treatment indicator equaling one if participant $i$ is in the LRT users group and zero for the comparison group; and $\mathbf{X}_i'\beta$ represents the two confounders (race and plans to use LRT in future) that remained different between groups after adjustments were made in the propensity score model. The parameter $\beta_2$ denotes the treatment effect of LRT use.

**Table 1.** Comparison of treatment and control subjects on baseline covariates before and after weighting

| Selection variables | Use LRT (*n*=26) | No LRT, unweighted (*n*=275) | No LRT, weighted (ESS=68.27) | Effect size |
|---|---|---|---|---|
| Gender (male=1) | 0.462 | 0.462 | 0.475 | −0.026 |
| Race (black=1, other=0)[a] | 0.308 | 0.113 | 0.198 | 0.234 |
| Age (years) | 42.34 | 46.65 | 43.59 | −0.09 |
| Employed (yes=1, no=0) | 0.692 | 0.781 | 0.686 | 0.013 |
| Miles to work (mean) | 10.41 | 11.91 | 10.46 | −0.004 |
| Education (level) | 2.80 | 2.78 | 2.65 | 0.166 |
| Rent (yes=1, no=0) | 0.269 | 0.114 | 0.267 | 0.006 |
| Social and physical environment (*z*-units) | 0.239 | −0.074 | 0.088 | 0.108 |
| Plan to use LRT[a] | 0.579 | 0.085 | 0.547 | 0.241 |

*Note:* ESS is the approximate number of observations from a simple random sample needed to obtain an estimate with sampling variation equal to the sampling variation obtained with the weighted comparison observations. The ESS gives an estimate of the number of comparison participants that are comparable to the treatment group of LRT users. Effect size is based on standardized mean comparisons.
[a]Denotes effect size >0.20 suggesting remaining substantive difference after weighting.
ESS, effective sample size; LRT, light rail transit

## Results

Table 2 presents summary statistics for all baseline (T1) variables. Respondents were on average aged 52 years; a slight majority were college educated (51%); 51% were employed full-time (12% part-time, 25% unemployed, 9% disabled, and 1.5% students); and 71.3% white and 21.2% black. In terms of objective measures of the physical environment, roughly 35% of study participants had a at least one recreational park located within a half-mile radius of their household and an average of 53 food and alcohol establishments within a 1-mile radius of their household. Approximately 38.4% of the respondents walked at least 30 minutes five times per week, and 64.1% reported exercising vigorously at least 20 minutes three times per week. Approximately 9.1% of respondents reported using public transit (rail and bus) on a regular basis (once a week or more) at baseline, prior to LRT exposure.

Table 2 also displays the results from the cross-sectional analysis of BMI, obesity, and meeting the RPA through walking and vigorous exercise. Positive perceptions of the social and physical environment in one's neighborhood were significantly correlated with lower BMI (b=−0.36, $p<0.05$) and a lower odds of obesity (OR=0.85, 95% CI=0.77, 0.94). The odds of meeting the weekly RPA through walking (OR=1.09, 95% CI=0.99, 1.20) and RPA through vigorous exercise (OR=1.11, 95% CI=1.01, 1.22) were significantly higher for those living in neighborhoods with more-positive social and physical environments. The odds of meeting the RPA for vigorous exercise were 11% higher for an SD increase in positive perceptions of the social and physical environment. The density of food and alcohol establishments around one's residence was associated with 25% higher odds of meeting RPA from walking (OR=1.25, 95% CI=1.04, 1.51) but not significantly associated with meeting RPA through vigorous exercise (OR=1.20, 95% CI=0.97, 1.48).

Table 3 displays the results from the main outcome analysis that equalizes differences between LRT users and non-LRT users. After adjusting the two groups to be statistically similar on pre-LRT exposure variables, there is a significant association between LRT use and reductions in BMI over time. Specifically, LRT reduced their BMI by an average of 1.18 $kg/m^2$ compared to similarly situated non-LRT users over a 12–18 month follow-up period. For a person who is 5′5″, that is equivalent to a relative weight loss of 6.45 lbs. Use of LRT is also associated with a reduced odds of becoming obese (OR=0.19, 95% CI=0.04, 0.92). LRT users were 81% less likely to become obese over time. The odds of increasing one's physical activity through vigorous exercise to meet RPA levels is also associated with LRT use (OR=3.32, 95% CI=0.81, 3.63) but was only significant at the $p<0.10$ level. The association between LRT use and meeting weekly RPA levels of walking was in the positive direction (OR=1.36, 95% CI=0.39, 4.73) but not significant.

## Discussion

The results from the initial cross-sectional analysis indicate significant associations among perceptions of neighborhood environments, BMI, obesity, and meeting weekly RPA levels. To address the issue of selection bias

**Table 2.** Sample characteristics, BMI, obesity, and recommended physical activity at baseline

| Characteristics | *n* | %, or M (SD) | BMI (*n*=660) (estimate [*t*-value]) | Obese (*n*=660) (OR [95% CI]) | RPA (*n*=660), walking (OR [95% CI]) | RPA (*n*=667), vigorous (OR [95% CI]) |
|---|---|---|---|---|---|---|
| **BMI** | 801 | 27.0 (12.39) | — | — | — | — |
| **Obese (≥30 BMI)** | 801 | 23.2 | — | — | — | — |
| **Met vigorous physical activity** | 817 | 64.1 | — | — | — | — |
| **Met walking physical activity** | 825 | 38.4 | — | — | — | — |
| **Gender (% male)** | 732 | 42.3 | 0.99 (2.19)* | 1.16 (.79, 1.71) | 0.97 (0.70, 1.34) | 1.54 (1.10, 2.17)* |
| **Race** | 839 | — | — | — | — | — |
| White | — | 71.3 | — | — | — | — |
| Black | — | 21.1 | 2.23 (3.44)* | 2.22 (1.36, 3.63)* | 0.71 (0.44, 1.15) | 0.81 (0.51, 1.31) |
| Other ethnicity | — | 6.9 | — | — | — | — |
| **Age** | — | 52.1 (16.3) | 0.045 (2.85)* | 1.00 (0.99, 1.02) | 0.99 (0.98, 1.00) | 0.98 (0.97, 0.99)* |
| **Employed full-time (=1)** | 837 | 52.1 | 1.03 (2.02)* | 1.41 (0.90, 2.21) | 0.94 (0.65, 1.35) | 1.36 (0.94, 1.98) |
| **Education (M)** | 833 | 2.44 (1.03) | −0.204 (0.83) | 0.91 (0.74, 1.12) | 0.92 (0.77, 1.09) | 1.01 (0.84, 1.21) |
| ≤High school | — | 23.6 | — | — | — | — |
| >High school | — | 25.2 | — | — | — | — |
| College degree | — | 33.8 | — | — | — | — |
| Graduate degree | — | 17.2 | — | — | — | — |
| **Rent (=1) or own** | 826 | 22.6 | 2.41 (3.93)* | 1.82 (1.13, 2.93)* | 1.34 (0.87, 2.07) | 0.79 (0.51, 1.23) |
| **Social and physical environment (*z*-units)** | 804 | 0.00 (1.77) | −0.358 (2.78)* | 0.85 (0.77, 0.94)* | 1.09 (0.99, 1.20)** | 1.11 (1.01, 1.22)* |
| Presence of park (within half mile) | 839 | 35.8 | 0.153 (0.29) | 0.85 (0.54, 1.33) | 0.73 (0.50, 1.06) | 1.01 (0.68, 1.49) |
| Density of food and alcohol outlets (no. within half mile) | 766 | 51.52 (51.7) | −0.281 (−1.07) | 0.93 (0.75, 1.17) | 1.25 (1.04, 1.51)* | 1.20 (0.97, 1.48)** |
| Residential density (households per square mile) | — | 1326.9 (754.9) | −0.00 (0.82) | .99 (.99, 1.00) | 1.00 (.99, 1.00) | 0.99 (.99, 1.00) |
| Take public transit (≥once a week) | 837 | 9.1 | −1.01 (−1.24) | 1.15 (0.61, 2.15) | 1.23 (0.69, 2.20) | 1.06 (0.58, 1.93) |

*Note:* Density of food outlets was converted into SD units in outcome models. Estimate = linear coefficient.
*$p<0.05$; **$p<0.10$
RPA, recommended weekly physical activity

**Table 3.** Effects of using LRT on changes in BMI and physical activity

| | Estimate | *p*-value |
|---|---|---|
| | ***B* (95% CI)** | |
| BMI (change T2–T1) | −1.18 (−2.22, −0.13) | 0.015 |
| | **OR (95% CI)** | |
| Obesity (change T2–T1) | 0.19 (0.04, 0.92) | 0.039 |
| Met walking physical activity (change T2–T1) | 1.36 (0.39, 4.73) | 0.48 |
| Met vigorous physical activity (change T2–T1) | 3.32 (0.81, 13.63) | 0.094 |

*Note:* Baseline plans to use LRT (=1) and race (black=1) were controlled for.
*B*, linear coefficient; LRT, light rail transit

endemic in cross-sectional studies of the relationships among the built environment, physical activity, and obesity, a pre–post assessment was used of individuals residing in neighborhoods that were exposed to LRT. A propensity score model was used to control for baseline confounders associated with the likelihood of LRT use and found that LRT users experienced a significant reduction in BMI and were less likely to become obese compared to similarly situated individuals who did not use LRT. These findings suggest that daily LRT use provided assistance in weight control, independent of preexisting differences in the built environment. Importantly, LRT users and their comparison group were living in the same neighborhoods with similar commuting patterns, perceptions of neighborhood environments, and other potential confounders.

The implied average loss of 6.45 lbs induced by LRT use may be plausible if a person added walking 1 mile every workday to his or her daily routine. For a person weighing about 150 pounds, walking an extra 1 mile for 250 days/year would burn about 20,000 additional calories, or the equivalent of nearly 6 pounds. The average distance from home to the nearest station stop among LRT users was 1.5 miles, with bus stops located on average within 0.25 miles of their homes. The average estimated distance from a LRT station stop to a work address among LRT users was 0.35 miles. Using LRT could increase walking by approximately 1.2 miles a day, if one assumes that those using LRT to commute to work would walk to a bus stop to take to the local LRT station, and then walk from the destination stop to their work address. The estimate of additional walking induced by LRT use in the present study is close to what would be necessary to generate the average weight loss observed. The average estimated weight loss observed seems reasonable given it is less than the average weight loss of 8.8 lbs induced by caloric reduction diets.[49]

The findings from the current study suggest that increasing the access to LRT transit for individuals to commute to work may help overcome some of the barriers to engaging in daily utilitarian exercise. The longitudinal data used here charted RPA levels and BMI before and after being exposed to the LRT line in specific neighborhood environments and suggests a link between use of LRT and positive health outcomes. Because the data from the present study involved a pre–post design where LRT was naturally introduced into respondents' neighborhoods, the effects observed are most likely associated with use of the LRT, as they are independent of observed baseline differences in factors associated with transit use and residential locations. The extent to which meeting RPA levels occurs through walking directly to transit lines is not known. The average distance between home and work locations and transit stops does suggest that using LRT likely increases utilitarian exercise to levels consistent with weekly RPA levels.

## Study Limitations

There are several important limitations to the current study. The most obvious one is that BMI and RPA measures were obtained by self-report and not by objective means. The measures of RPA are rough proxies of an individual's self-reported weekly walking and vigorous exercise patterns. There is likely substantial reporting error in estimates of these outcomes. For example, the measure of meeting vigorous RPA is likely high because of self-reporting bias. Perhaps LRT users were more likely than the comparison group of non-LRT users to underreport BMI. There also may be additional omitted variables that are confounded with LRT use that explain the LRT use and BMI association. In addition, the percentage of LRT users was quite small, and although the findings were significant, the CIs are quite wide, suggesting that future studies should enroll much larger sample sizes. Furthermore, there was a sizable loss of sample in follow-up, primarily because of the need to continuously reside in the catchment area. Establishing the potential long-term effects of light rail use on obesity will require subsequent follow-up studies with larger samples of individuals that specifically measure walking distances through pedometers or other related technologies.

## Policy Implications

Understanding ways to encourage greater use of local environments for physical activity offers some hope for reducing the growth in the prevalence of obesity. Given that perceptions of neighborhood environments are independently associated with improved health outcomes, and that individuals who choose to use LRT obtain some relative weight reduction, it would be prudent to encourage public policies that improve the safety and attractiveness of pedestrian environments that link home, work, and transit stops to increase use of public transit for commuting to work. Public policy investments in transit should consider potential increases in physical activity as part of the broader set of cost–benefit calculations of transit systems.

Land-use planning and travel choice have a clear impact on health outcomes.[50,51] Public transit systems can generate positive health impacts by encouraging greater numbers of users to walk to station stops and maintain more physically active lives. An added benefit of public policy investments in LRT, on top of the general transportation benefits accrued, is the potential reductions in obesity in the population. There are currently 32 LRT systems operating in major U.S. metropolitan areas and generating more than 200 million passenger trips a year.[52] Other studies of LRT use indicate that the population density and number of stops in residential areas, rather than commercial destinations, predict higher levels of daily ridership in U.S. light rail systems.[53] Increasing the use of LRT for those within proximity to existing systems should be encouraged as a potential weight maintenance strategy along with other lifestyle benefits.

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