Invited Commentary

Invited Commentary: Taking Advantage of Time-Varying Neighborhood Environments

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Neighborhood built environment characteristics may encourage physical activity, but previous literature on the topic has been critiqued for its reliance on cross-sectional data. In this issue of the Journal, Knuiman et al. (Am J Epidemiol. 2014;00(00):0000–0000) present longitudinal analyses of built environment characteristics as predictors of neighborhood transportation walking. We take this opportunity to comment on self-selection, exposure measurement, outcome form, analyses, and future directions. The Residential Environments (RESIDE) Study follows individuals as they relocate into new housing. The outcome, which is neighborhood transportation walking, has several important limitations with regards to public health relevance, dichotomization, and potential bias. Three estimation strategies were pursued: marginal modeling, random-effects modeling, and fixed-effects modeling. Knuiman et al. defend fixed-effects modeling as the one that most effectively controls for unmeasured time-invariant confounders, and it will do so as long as confounders have a constant effect over time. Fixed-effects modeling requires no distributional assumptions regarding the heterogeneity of subject-specific effects. Associations of time-varying neighborhood characteristics with walking are interpreted at the subject level for both fixed- and random-effects models. Cross-sectional data have set the stage for the next generation of neighborhood research, which should leverage longitudinal changes in both place and health behaviors. Careful interpretation is warranted as longitudinal data become available for analysis.

longitudinal studies; multilevel analysis; residence characteristics

Abbreviation: RESIDE, Residential Environments.

Health promotion strategies targeting the neighborhood built environment (1) may encourage physically active lifestyles (2, 3), perhaps extending years of healthy life and independent living (4–6). Yet, the largely cross-sectional evidence on neighborhood characteristics and physical activity is difficult to interpret because there are multiple competing causal and noncausal explanations (7, 8). In this issue of the Journal, Knuiman et al. (9) present a longitudinal analysis of built environment characteristics from the Residential Environments (RESIDE) Study as predictors of neighborhood transportation walking. Although we agree on the untapped potential value of incorporating a longitudinal approach into neighborhood research, we take this opportunity to comment on issues related to self-selection, exposure measurement, outcome form, analysis methods, and future directions.

SELF-SELECTION AND THE NEED FOR LONGITUDINAL NEIGHBORHOOD RESEARCH

Comprehensive longitudinal data can support or disconfirm the presumed causal effects of the local built environment on health and health behaviors by systematically examining 2 key noncausal explanations: confounding by common prior causes related to both health and neighborhood selection (10) and reverse causation whereby physical activity or subsequent health affects neighborhood selection (11, 12). Self-selection of physically active or healthy people into desirable neighborhoods may explain observed cross-sectional associations between built environment characteristics and physical activity level (7, 10, 13, 14). For example, individuals who prefer walking over other modes...
of transportation may select a neighborhood with more potential walking destinations; in fact, the association between destinations and walking may be stronger among persons with a positive attitude toward walking (15). Knuiman et al. (9) offer within-subject estimates of the association as a strategy to limit confounding due to self-selection and conclude that the observed associations are robust. However, they appropriately note that their results may be affected by changes over time, such as declines in health status or changes in household composition, that potentially affect both neighborhood selection and walking behaviors.

The within-subject built environment–walking association observed by Knuiman et al. (9) represents a step toward understanding the causal relationships of interest. However, biases related to neighborhood selection may take different forms in other populations or subpopulations. In particular, socially advantaged individuals may use their resources to get a better match between their health-related preferences and their neighborhood, whereas the constrained housing options of disadvantaged populations may not allow as much room for preferences to be factored in. Indeed, several studies have documented stronger associations of the local built environment with physical activity–related outcomes among affluent populations (16–18), whereas safety concerns may be more crucial in low-income settings (19–21). Future work in diverse populations may help to distinguish the relative importance of environmental influence and neighborhood self-selection for particular population subgroups.

EXPOSURE: NEIGHBORHOOD WALKABILITY AS A TIME-VARYING CHARACTERISTIC

People move to new residential locations throughout their lives, and such moves represent potential changes in exposure to neighborhood characteristics, such as walkability. Likewise, changes to the local environment could affect a residentially stable population. Both of these may serve to make neighborhood characteristics vary by time in a longitudinal study design, such as a natural experiment (22). The RESIDE Study (9) blends individual mobility and neighborhood change data by following individuals as they relocate into a new housing development in which they had indicated at baseline that they were having a house built. This represents an important complement to approaches based on public housing subsidies (23, 24). However, comparisons across the spectrum of housing types (public, rental, owner-occupied) may require future studies with a wider target population.

Evaluating the health implications of new housing developments or investments in existing residential environments has great potential. However, natural experiments are by definition outside of researcher control and may not always provide a valid test of the research question of interest. In this case, it is not clear whether the new developments were consistently more pedestrian supportive because of limited transit infrastructure and peripheral location. This issue is not unique to the RESIDE Study. The Healthy Promoting Livable Active Community Environments (PLACES) Trial also used a longitudinal design to evaluate a new residential community. The Healthy PLACES investigators found that the adherence to smart growth principles (which the natural experiment was designed to assess) was limited because of factors outside of investigator control (25). Nonetheless, the strategy to study people from imminently relocating households allows for longitudinal analyses and comparisons among and within individuals over time. This somewhat reframes the utility of natural experiments for neighborhood research, pointing to the importance of capturing moments of change (whether for better or for worse) to allow for the temporality of any associations with neighborhood context to be investigated.

Although discordance between self-reported and independently assessed neighborhood characteristics has been noted previously (26, 27), the investigators of the RESIDE Study are in a unique position to consider these in a longitudinal context. We hope that in future work, the data will be used to aid our understanding of whether self-reported neighborhood characteristics (e.g., destination accessibility) become more aligned with independently assessed measures for longer duration of residence. Previous studies offered a model for giving direct attention to the concordance of neighborhood characteristics as measured using questionnaires or geographic information systems (27, 28). However, in the study by Knuiman et al. (9), self-reported and independently assessed neighborhood characteristics were mainly considered in parallel, with both being subject to change after relocation to a new home address. As in previous studies (29, 30), physical activity associations were somewhat stronger when environment measures were based on self-report.

OUTCOME: ANY NEIGHBORHOOD WALKING FOR TRANSPORTATION (VERSUS NONE)

Knuiman et al. (9) used a previously validated measure of transportation walking within the neighborhood (31) as their outcome. Neighborhood transportation is likely optimized to correlate with the neighborhood built environment characteristics of interest (29, 32, 33). However, this neighborhood transportation walking outcome has several important limitations with regard to public health relevance, dichotomization, and potential for bias.

First, although built environment studies have typically found stronger associations with transportation walking, studies with clinical health outcomes like cardiovascular disease typically find stronger associations with walking for exercise (versus transportation), perhaps because the walking is done at a faster pace or with more regularity (12, 34). In any case, it may be that for some health outcomes, walking for transportation within one’s neighborhood represents too small a fraction of total physical activity to cause a detectable health benefit.

The dichotomization of the outcome of neighborhood transportation walking into any versus none also raises concerns (35). Although the built environment might be expected to subtly encourage more walking among persons who like to walk, this would not be detected. The longitudinal within-subject analyses rely on transitions from any neighborhood transportation walking to none (or none to any), which may be confounded by changes in health, household composition, employment, work environment, or commute length. Finally, the dichotomized measure represents a common outcome, making odds ratios difficult to interpret (35–38).

The precision of self-reported physical activity measures is known to be low and subject to differential measurement
error across sociodemographic groups (39, 40). Social desirability bias could affect reports differentially by neighborhood or across demographic groups (39), and such differential bias could contribute to the observed findings of Knuiman et al. (9) and the pattern of stronger associations with perceptions (due to correlated errors between self-reports of neighborhood characteristics and of walking).

Further, it was not clearly specified whether neighborhood transportation walking was the a priori main outcome or whether other walking-related (41, 42) and physical activity—related (43–45) outcomes available in the RESIDE Study were tested as well. In general, multiple comparisons and publication bias have received insufficient attention in the literature on built environments and physical activity, a trend that will hopefully change as meta-analyses of this literature emerge (46, 47).

**ANALYSIS METHODS AND REPORTING STANDARDS: MARGINAL, RANDOM, AND FIXED EFFECTS**

To examine the longitudinal association between built environment characteristics and neighborhood transportation walking, Knuiman et al. (9) pursued 3 estimation strategies: marginal modeling, random-effects modeling, and fixed-effects modeling. The authors adequately described the variables included in the models, although they used nonstandard terminology to describe their missing data. More specific documentation of the assumed marginal correlation structure and the random effects (individual-level intercepts) would be helpful in understanding how each strategy was implemented.

The results from each modeling strategy are presented by Knuiman et al. (9), providing context for us to offer a short discussion of the tradeoffs of fixed-effects versus random-effects modeling. Fixed-effects modeling protects against bias due to unmeasured time-invariant confounders as long as those confounders have a constant effect over time (which is emphasized here because the article by Knuiman et al. (9) did not make it explicit). Fixed-effects modeling also requires no distributional assumptions regarding the heterogeneity of subject-specific effects. Both of these are useful features that provide a check for some of the assumptions in a random-effects model. However, fixed-effects modeling has 2 important disadvantages: 1) the inability to estimate effects of time-invariant covariates like race and sex (the authors include sex, presumably as a time-varying covariate, but do not indicate to what extent gender varies over time in this data set) and 2) the limited ability to assess heterogeneity across individuals because subject-level variance estimates are not provided.

These drawbacks are important because Knuiman et al. (9) restricted themselves to marginal and random-effects models and analyses that are analogous to the fixed-effects model. Specifically, because the associations of time-invariant characteristics with the outcome cannot be estimated in the fixed-effects framework, the authors do not assess these relationships elsewhere. They therefore do not emphasize, for example, race- or sex-based disparities in walking and are unable to comment on the potential need for interventions that reduce these disparities. These associations can be estimated in either the marginal or random-effects model, and it would be informative to do so. The article by Knuiman et al. also lacks information on or interpretation of heterogeneity in the population. The random intercept variance would be useful to describe, for instance, because this heterogeneity contributes to the expected attenuation of contextual associations when comparing marginal and random-effects models.

Finally, we argue that in the context of the RESIDE Study (9), the best interpretation may be given by the marginal model. Neighborhood structure affects populations of subjects, so the associations of neighborhood structure with walking are best understood at the population level (48). Of course, both fixed- and random-effects model coefficients are interpreted at the subject level.

With a dichotomous outcome, the population-averaged odds ratio will generally be closer to the null than will the conditional odds ratio, as was seen in the findings of Knuiman et al. (9). They suggested that comparisons of the results from their different modeling strategies can enable assessment of bias arising from self-selection. A correct and guarded interpretation will be essential in any future discussions of neighborhood-level interventions to promote walking.

**FUTURE RESEARCH RECOMMENDATIONS FOR POLICY RELEVANCE**

There would seem to be an important missing step in the argument by Knuiman et al. (9) that 1) physical activity is of great public health importance, 2) the built environment measures in their study are associated with whether a person engages in any neighborhood transportation walking, and thus 3) the built environment should be changed to support local transportation walking. Even if the longitudinal associations shown are causal, such changes to the built environment and local transportation walking would not necessarily change total physical activity levels and thus result in health benefits. Characteristics of the local environment may just cause a shift to transportation walking (versus recreational walking) or to walking near the home (versus at some other location). Meanwhile, even if built environment is relevant to total physical activity level, there are costs and tradeoffs to be considered—given finite financial resources and resident preferences, should neighborhood-level interventions to enhance transportation walking be favored as targets over other priorities?

Cross-sectional data have set the stage for the next generation of neighborhood research that leverages longitudinal changes in both place and health behaviors (49). Although we agree that the longitudinal design overcomes some limitations of previous research, we do not think that the causal relationship is confirmed, and we suggest that the built environment features that were studied may be correlated with other features. Future natural experiments would benefit from reduced reliance on any single change to the environment, perhaps instead comparing multiple new housing developments, transit infrastructure expansions, or other changes to the environment resulting from policy initiatives or commercial investment decisions.

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