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Associations between building design, point-of-decision stair prompts, and stair use in urban worksites

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ABSTRACT

Objective. Incidental forms of physical activity such as stair use offer frequent opportunities for energy expenditure and may contribute to the prevention and control of chronic diseases. This study analyzes the associations between building characteristics, stair prompts, and stair use in large urban worksites.

Methods. Bootstrapped generalized mixed models were used to analyze self-reported stair use, using data from 1348 surveys of city employees and fourteen building assessments conducted in New York City in 2012.

Results. 57% of respondents reported climbing ≥1 flights of stairs daily at the workplace. Model results show that stair prompts were associated with a 3.21 increased likelihood of stair use. Naturally lit stairwells and stairwell visibility were also positively associated. Higher floor residency and BMI were negatively related, as were gender, stairwell distance from lobby entrances, the total number of floors in each building, and building averages for BMI and gender. Residual heterogeneity measured by adjusted median odds ratios indicates that buildings can have a moderate effect on the likelihood of stair use beyond those of individual characteristics.

Conclusions. Specific building features and stair prompts may potentially be leveraged to positively influence rates of incidental physical activity and contribute to improvements in population health.

Introduction

Stair use as form of incidental physical activity offers daily opportunities for energy expenditure, and may contribute to the prevention and control of chronic diseases. The built environment can promote the determinants of incidental physical activity by shaping the structural design of neighborhoods and buildings, where small changes to the environment can have large effects on the population and reduce the rate of sedentary behavior (Frank et al., 2003). As chronic conditions and the negative health effects associated with obesity disproportionately afflict minority and economically underserved populations, there is an established need for large-scale preventive health measures. The need is especially glaring in New York City, where 21% of adults report no leisure-time physical activity over the past thirty days, 32% of adults are overweight, and 24% of adults are obese (Epiquery, 2012). More and more, traditional physical activity interventions such as educational programs and media campaigns are being replaced by environmental modifications that promote new ways of being physically active, such as bike lanes, building interventions to increase stair use and walkability, and locating large urban housing complexes within walking distance of work, school, and exercise facilities.

Evidence of the relationship between stair climbing and health is diverse, with varying levels of effectiveness. The Harvard Alumni Health Study showed that climbing stairs with at least a moderate intensity (≥4.5 METs) was associated with a reduced stroke risk, but no relationship was found with light intensity (Lee and Paffenbarger, 1998). In a clinical study of sedentary women, researchers found that gradual increases in stair use (ascending from one to six flights over time) improved cardiovascular health and cholesterol levels, and concluded that short bouts of stair climbing throughout the day can positively influence cardiovascular risk factors when moving from a previously sedentary lifestyle (Boreham et al., 2000). Other research shows positive associations between stair use and mortality, longevity, muscular strength, and aerobic capacity (Boreham et al., 2000; Loy et al., 1994; Paffenbarger et al., 1997; Teh and Aziz, 2002). Stair use requires 8.6–9.6 times greater energy expenditure than resting states, and cardiovascular benefits have been found among individuals who climbed over twenty flights of stairs per week (Bassett et al., 1997; Teh and Aziz, 2002). However, calorie expenditures from short stair use periods may not be immediately apparent (Paffenbarger et al., 1997).

While physical activity from stair use may or may not meet the recommendations of the American Heart Association (Fletcher et al., 1996), it has been argued that incidental physical activity can facilitate the progression to more rigorous exercise (Andersen et al., 1999). Stair use may be one such mechanism. People are more likely to use stairs that are prominently displayed (Nicoll, 2007) and visually appealing (Boutelle et al., 2001), and stairwells that are visible and accessible from main travel areas are more likely to be used for everyday commutes. Additionally, the implementation of stair prompts at elevators and escalators that encourage taking the stairs and promote the health benefits of physical activity has been associated with greater stair use in public

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areas (Coleman and Gonzalez, 2001; Eves, 2010; Eves et al., 2008; Kerr et al., 2001; Lewis and Eves, 2011; Lee et al., 2012; Müller-Riemenschneider et al., 2010; Nocon et al., 2010; Puig-Ribera and Eves, 2010; Soler et al., 2010; van Nieuw-Amerongen et al., 2011).

In this study, we explore stair prompts and associated stair use in worksite settings, and identify the specific building characteristics that may further lead to that use. We contribute to the extant built environment and physical activity literature by applying a multilevel framework to data on building design, individual characteristics, and stair prompt exposure, directly modeling the hierarchical relationship between environment and individual behavior. While previous research has investigated the links between stair prompts or building design and stair use in isolation, to our knowledge no study considers them together. Further, our study will demonstrate the applicability of previous findings to urban office buildings, characterized by large captive employee populations working in multistory buildings that can maximize stair use opportunities.

Methods

Data were collected from a convenience sample of fourteen NYC buildings managed by the Department of Citywide Administrative Services (DCAS), using an employee health and physical activity survey and a building assessment. The study was conducted by the Bureau of Chronic Disease Prevention and Tobacco Control at the NYC Department of Health. Prior to survey administration, stair prompts were posted at elevator call buttons and stairway entry doors from February to June, 2012. Prompts encouraged employees to "burn calories, not electricity" by using the stairs in lieu of elevators, and highlighted the weight and environmental benefits associated with stair use.

A dichotomous outcome was used indicating at least one flight of stairs climbed per day, computed from the survey question "At your work building on a typical weekday, how many floors of stairs in total do you climb up". Employees were nested in buildings. As a sensitivity analysis, we conducted an additional model where the outcome represented at least three flights of stairs climbed per day. Outcomes were selected because physical inactivity is associated with an increased risk of cardiovascular disease, diabetes, and osteoporosis. As such, moving from sedentary behavior to any form of physical activity is important. According to the 2008 HHS Physical Activity Guidelines, reducing inactivity can minimize health risks. The dose–response relationship between physical activity and the relative risk of all-cause mortality sees the greatest risk reduction in the lowest end of the physical activity spectrum.

Data

Health survey web-links were emailed to building managers who distributed them to employees vis-à-vis existing administrative lists, resulting in a sample size of 1348. Only city agency workers were invited to participate, who represent a proportion of the entire building occupancy. The use of city employees allowed for direct access to a large number of respondents across buildings within the study timeframe. Information on the total building population is unknown or is protected and not available to researchers.

Data were collected on age, sex, stair use frequency, and exposure to stair prompts. BMI was computed from height and weight. Building assessments recorded data on the total number of floors, the measured distance from lobby entrances to stairs, stairwell visibility from lobby edges and elevator vestibules, the presence of open, unenclosed stairwells, and whether stairwells are illuminated via natural light sources. Prior to analysis, any participants who reported that they were physically incapable of using the stairs were removed (ten cases). Stair use questions were modified from the 2010 Community Health Survey (CHS), an annual complex survey conducted by the NYCDOH. The 2010 CHS includes validated questions for stair use from both home and work sources. We modified these questions to include only stair use at worksites. The instrument itself is not validated.

Statistical analysis

A two-level generalized mixed model was used to predict the likelihood of stair use (Raudenbush and Bryk, 2001). Individual-level predictors included BMI, gender, age, a dummy variable indicating stair prompt exposure, and employee resident floor level. Building variables included stairwell distance from lobby entrances, stairwell natural lighting, stairwell visibility from the lobby, the total floors per building, and average gender and BMI. Building-level predictors were entered into the model as fixed effects. To test a potential additive effect between walking distance and stair use over and above their individual contributions, a cross-level interaction between resident floor-level and stairwell distance was also included. We hypothesized that relative proximity to stairwells may have a synergistic effect with employee resident stair level in stair use decision making. For example, if stairwells are positioned far from building entrances, participants may elect to use the elevator even if they work on low-level floors.

Our sample had fourteen second-level units. Multilevel models with small level-2 sample sizes can bias variance components and standard errors (Hox and Maas, 2005). Simulation studies have shown that level-2 sample sizes of thirty groups can underestimate standard errors by approximately 15%, while even smaller samples can over-overestimate group-level variance components by 25% and further underestimate the standard errors for regression coefficients and variances. While the literature on sample size and multilevel modeling is primarily concerned with continuous outcomes, there is general agreement as to the importance of level-2 sample size, which can increase statistical power for second-level parameters and cross-level interactions (Hox, 2002; Timberlake, 2011). Less is known regarding the extent of bias in multilevel logistic regression; however binary logistic models have more stringent sample size requirements than standard OLS regression. It has been shown that level-2 sample size can bias estimates in multilevel logistic regression under certain model conditions (Timberlake, 2011).

Bootstrapping can be used in a multilevel framework to correct for bias in parameter estimates and allow for non-parametric inference (Hox and Maas, 2004; Roberts and Fan, 2004; Wang et al., 2006). We modified a nested case resampling algorithm to provide robust estimates, which nests the bootstrap within level-2 units and provides consistent bootstrapped sample sizes across each iteration, a feature lacking in residual bootstrap methods (Roberts and Fan, 2004). The mixed model was added to the bootstrapping macro, and 2000 iterations were run with an original level-1 sample size of 1338. All analyses were conducted using SAS version 9.2.

The intraclass correlation coefficient (ICC) was derived from the unconditional model using the latent variable method, indicating that a high proportion of variance (.38) in stair use was accounted for at the building level (Merlo et al., 2006; O'Connell et al., 2008; Snijders and Bosker, 1999). As interpreting ICCs in logistic multilevel models can be difficult, we computed the median odds ratio (MOR) as a secondary measure of cluster heterogeneity (Merlo et al., 2006). The MOR translates building-level variance into an odds ratio and quantifies the individual probability of stair use as determined by buildings. As described previously, estimated MORs provide the change in risk that the median case (e.g., a person) would expect when moving from an area of low risk to an area of high risk. In this case, risks are probabilities of stair use. As with the ICC, the resulting median odds ratio of 3.8 for the null model indicates that building features substantially contribute to the variation in individual stair use. Finally, we provide 80% Interval Odds Ratios (IOR-80) to quantify cluster-level variable effects. The IOR-80 includes residual area-level variation to assist in interpreting effects of building-level variables (Larsen and Merlo, 2005).

Results

Overall, 56.7% of participants reported ascending at least one flight of stairs per day. 54.5% of respondents were female, and the average BMI was 26.8. The most common age category was 45–54 (25.8%), followed by 35–44 (22.6%), 25–34 (22.2%), and 55–64 (17.1%). Both the 18–24 and ≥65 age groups made up 3% of the sample. Age categories were collapsed into four groups for model analyses. Building assessment data show that the average distance from lobby edges or vestibules to stairwell entrances is 15.9 m. Four buildings had stairwells that were visible from the lobby, and seven buildings had stairwells that had a direct source of natural light. A summary of stair use by age, sex, and BMI is presented in Table 1. A majority of respondents across all age groups reported taking no flights of stairs per day, and similar results were found for males and females and within each BMI category (normal weight, overweight, and obese). Typically, the proportion of stair users decreases as the number of stair flights increases.