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Effects of Green Buildings on Employee Health and Productivity

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We investigated the effects of improved indoor environmental quality (IEQ) on perceived health and productivity in occupants who moved from conventional to green (according to Leadership in Energy and Environmental Design ratings) office buildings. In 2 retrospective–prospective case studies we found that improved IEQ contributed to reductions in perceived absenteeism and work hours affected by asthma, respiratory allergies, depression, and stress and to self-reported improvements in productivity. These preliminary findings indicate that green buildings may positively affect public health. (*Am J Public Health.* 2010;100:1665–1668. doi:10.2105/AJPH.2009.180687)

The effect of indoor environmental quality (IEQ) in office buildings on employee health, well-being, and productivity is an important topic in occupational health and public health research and practice. IEQ can negatively affect occupants' physical health (e.g., asthma exacerbation and respiratory allergies) through poor air quality, extreme temperatures, excess humidity, and insufficient ventilation and psychological health (e.g., depression and stress) through inadequate lighting, acoustics, and ergonomic design.[1–12] Studies have shown that employees with such adverse health conditions are absent more often, lose more work hours, and are less productive than employees without these conditions.[13–18] The green building movement is attempting to address IEQ and employee health concerns by providing healthier building environments. Although the claim that improved IEQ also improves health and productivity is made in many qualitative studies[19–29] and has provided substantial motivation to build green,[30,31] quantitative studies are needed to validate these relationships.[15,32]

We evaluated changes in employee-perceived asthma and respiratory allergy symptoms and depression and stress conditions and the effect of these perceived changes on self-reported absenteeism, work hours affected, and productivity changes, following the movement from traditional to green (according to Leadership in Energy and Environmental Design [LEED] ratings) office buildings.[33] We focused on LEED-rated buildings because they dominate the US green building market,[34] and they are designed and constructed to optimize IEQ.

We carried out 2 case studies in the area of Lansing, Michigan, with a retrospective–prospective cohort design to evaluate the effects of moves to green buildings on perceived employee outcomes. The preliminary findings from these longitudinal studies will provide substantive direction for future occupational and public health initiatives, researchers, and public health policymakers.

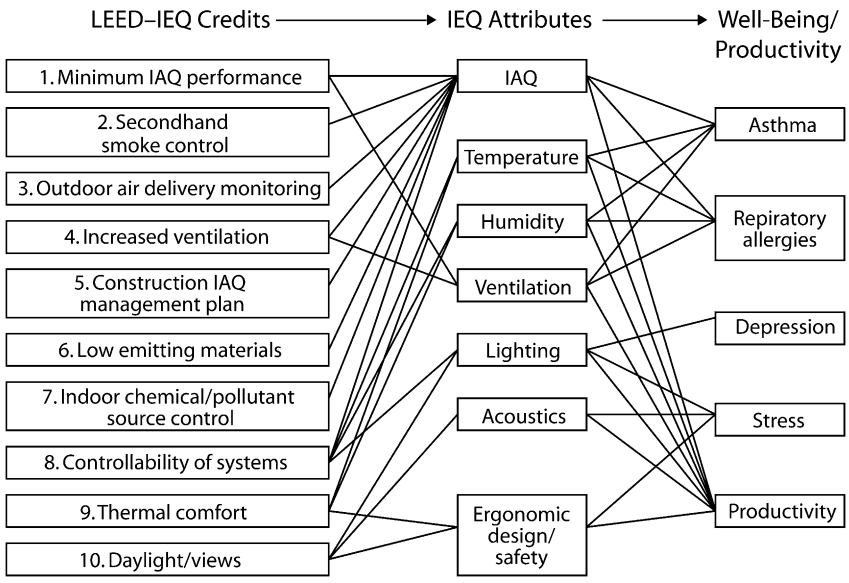
METHODS

We conducted 2 case studies in which we followed employees (study 1, n=56; study 2, n=207) who moved from conventional office buildings to LEED-rated buildings in Lansing, Michigan. LEED ratings range from Certified (lowest) to Silver, Gold, and Platinum, according to a system of LEED–IEQ credits defined by 7 attributes: indoor air quality, temperature, humidity, ventilation, lighting, acoustics, and ergonomic design and safety.[8] Figure 1 links these attributes with LEED–IEQ credits and selected health and productivity outcomes. The study 1 building was awarded the platinum LEED rating, and the study 2 building received a gold rating.[35]

Premove and postmove surveys were conducted with Web-based survey instruments that took employees approximately 20 minutes each to complete. We developed the surveys after reviewing the literature assessing other relevant health questionnaires.[21,33–36] We pretested the surveys and finalized them after receiving feedback from industry and academic experts. We conducted the premove survey for study 1 employees 3 to 4 months after their move; it was therefore retrospective. The study 2 employees responded to the premove survey while they still occupied the conventional building. The premove survey response rate for study 1 was 58.9% (n=33) and for study 2, 68.5% (n=142).

For study 1, we conducted the postmove survey 3 months after the premove survey (i.e., 6–7 months after the move); the response rate was 57.1% (n=32). The postmove survey for study 2 occurred 1 to 2 months after the premove survey (i.e., 4–6 weeks after the move); the response rate was 54.5% (n=113). The total study period was approximately 8 months. We downloaded both survey data sets into Excel spreadsheets (Microsoft Corp, Redmond, WA) and analyzed them in Excel and Minitab15[36] software programs.

We used the lower-tailed paired *t* test to determine the mean difference in perceived work hours affected and productivity change between paired observations (i.e., employees who completed both the pre- and postmove surveys). The paired *t* test computes a confidence interval and performs a hypothesis test of the difference between 2 population means when observations are paired and the paired differences follow a normal distribution. The paired differences in the pre- and postmove survey of outcomes reported by employees were normally distributed and therefore met



Note. IAQ = indoor air quality. The LEED credits listed here represent typical IEQ-related concerns covered in LEED rating systems; however, different rating systems may use minor variations of these credits. Case study project 1 pursued all credits 1-10, and case study project 2 pursued all credits except credit 9.

FIGURE 1—Leadership in Energy and Environmental Design (LEED)–indoor environmental quality (IEQ) occupant well-being and productivity structure.

the criteria for performing the paired *t* test on the paired observations in our studies.

RESULTS

Demographic information collected during the premove survey (n=175 for both studies) showed that a majority of respondents were female (68.0%), White (86.8%), non-Hispanic (82.2%), college educated (64.0%), and married (64.6%). Respondents' ages were younger than 20 years (1.2%), 20 to 29 years (34.3%), 30 to 39 years (29.7%), 40 to 49 years (20.3%), and older than 49 years (14.5%). Employees described their positions and responsibilities as managerial–executive (22.9%), supervisory (15.4%), support staff (58.3%), or other (3.4%). Overall, 14.9% of employees reported a medical history of asthma; 28.6%, respiratory allergies; 14.9%, depression; and 33.7%, stress-related conditions.

The mean number of self-reported hours absent per month from asthma and respiratory allergies in the premove survey was 1.12 (range=0–18; n=49); in the postmove survey, it declined to 0.49 (range=0–8; n=34). The premove mean for self-reported hours absent per month for depression and stress-related conditions was 0.93 (range=0–13); after the move, it was 0.47 (range=0–12). The mean number of self-reported work hours affected per month by asthma and respiratory allergies was 16.28 (range=0–88; n=46) before the move and 6.32 (range=0–28; n=33) afterward. The mean number of self-reported work hours affected per month by depression and stress was 20.21 (range=0–88) before the move and 14.06 (range=0–88) afterward. Before the move, the mean perceived productivity (i.e., self-reported effect of IEQ on typical productivity) was –0.80% (range=–10.0% to 10.0%; n=128); afterward it was 2.18% (range=–10.0% to 10.0%; n=141).

Overall, we found substantial reductions in self-reported absenteeism and affected work hours as a result of perceived improvements in health and well-being. The employees also perceived a positive effect of their new work environment on their productivity.

Our paired *t* test results for mean differences in perceived work hours affected and productivity change for employees who completed the pre- and postmove surveys are shown in Table 1, as perceived annual work hours gained. These findings suggested that perceived improvements in asthma and respiratory allergies could provide 1.75 additional work hours per year (e.g., 0.41+1.34) to each employee with a medical history of these conditions. Similarly, employees with a medical history of depression or stress might gain 2.02 additional work hours per year because of reductions in their perceived work hours affected by these conditions. Finally, the improvements in perceived productivity were fairly substantial and could result in an additional 38.98 work hours per year for each occupant of a green building.

DISCUSSION

The literature on the health effects of green buildings claims that improved IEQ has a positive effect on health and well-being. Our findings in these preliminary studies lend support to expectations of improved IEQ and occupational health and public health outcomes from expanded use of green office buildings. Our case studies employed a longitudinal study design and collected data from employees who moved from conventional to LEED-rated buildings about their productivity and health symptoms before and after the moves. These quantitative data supplement previous qualitative studies about the benefits of green office buildings.

Limitations

Study 1 employees received their premove survey 4 to 6 weeks after their move into the LEED-rated building, so there was the potential for recollection bias. We tried to minimize this bias by asking respondents to rate their level of confidence when reporting their premove outcomes and excluding responses rated less than 50% confident. Previous comparisons of retrospective reporting of sickness and work absences with recorded employer data found minimal discrepancies,[37,38] suggesting that recollection bias in study 1 probably did not significantly affect the results.

We did not evaluate the recollection and perceptual bias of employees reporting their own health effects.[39] For example, employees

TABLE 1—Results From a Paired *t* Test for Well-being and Productivity Benefits Among Employees Who Moved From Conventional to Green Office Buildings: Sustainable Built Environment Project, Greater Lansing area, Michigan, 2008–2009.

Outcome	Mean Difference[a]	*P*[b]	Minimum Average Gains	Total Benefit per Year
Absenteeism attributable to asthma and respiratory allergies, d (n = 25)	0.034	.047	Reduced by 0.034 h/mo for each occupant reporting asthma or allergies	Additional 0.41 work hours/occupant
Work hours affected by asthma and respiratory allergies (n = 27)	2.35	.02	Reduced by 2.35 h/mo for each occupant reporting asthma or allergies	Additional 1.34 work hours/occupant reporting asthma or allergies[c]
Work hours affected by depression and stress (n = 34)	2.86	.02	Reduced by 2.86 h/mo for each occupant reporting depression or stress	Additional 2.02 work hours/occupant reporting depression or stress[d]
Direct effect of IEQ on productivity, hours (n = 86)	2.59	<.001	Productivity improved by 2.6% for all occupants	Additional 38.98 work hours/occupant[e]

Note. IEQ = indoor environmental quality.
[a]Mean difference of (premove – postmove) response for well-being and (postmove – premove) for productivity.
[b]Only statistically significant values (≥ 95% lower-bound confidence) are reported.
[c]The minimum average premove productivity loss as reported by respondents when facing asthma or respiratory allergies was calculated as 4.75%, yielding a postmove gain of 2.35 work hours, or 0.112 h/mo. Calculation performed with the lower-tailed *t* test and both pre- and postmove survey data.
[d]The minimum average premove productivity loss as reported by respondents when facing depression or stress conditions was calculated as 5.90%, yielding a postmove gain of 2.86 work hours, or 0.17 h/mo. Calculation performed with the lower-tailed *t* test and both pre- and postmove survey data.
[e]The minimum average premove productivity loss attributable to all health conditions as reported by all respondents was calculated as 0.565%. Calculation performed with the lower-tailed *t* test and both pre- and postmove survey data. For each month averaging 160 work hours, a 2.03% improvement equals 3.25 additional work hours.

may have perceived and acted upon (or not acted upon) their symptoms of asthma, allergies, depression, and stress differently, and these differences may have biased their recollection and perception of the outcomes reported in the pre- and postmove surveys. Ideally, it would have been beneficial to have observed these behaviors instead of relying on self-reports. In addition, independent data to verify employees' perception of absenteeism, work hours affected, and productivity (e.g., personnel records) were not available for these studies.

The pre- and postmove surveys were taken at different times of the year, so asthma and allergy symptoms reported before and after the moves may have been seasonally biased. The timing of the moves was decided by facility managers, and thus our pre- and postmove surveys were conducted at the beginning and end of the pollen seasons in Michigan. The premove survey for study 1 and study 2, conducted in April and May, obtained retrospective information on outcomes from study 1 in January and from study 2 in March and April. Both postmove surveys were conducted in September and October to obtain retrospective information on outcomes in August. In Michigan, different pollen types are released in early spring (e.g., trees and grasses) and fall (e.g., grasses and weeds), so fall pollen exposures may have resulted in less severe or fewer allergic reactions in our study population than did spring pollen exposures. Ideally, it would have been preferable to conduct the pre- and postmove surveys at the same time of year.

Perceived improvements in stress and depression after the move into the new LEED-rated buildings may have been the result of employees' excitement about their new work environment. The Hawthorne effect[15] explains such temporary bias in occupants' perception of their performance and satisfaction resulting from a change in the work environment. Other studies dispute the Hawthorne effect[40–42]; 1 contention is that increases in productivity after renovations were likely a result of the removal of obstacles that impede productivity.[42] Finally, we assumed that the projections of improvements in perceived work hours affected and productivity gains would be maintained over a year.

Future Research

Our preliminary analyses identified several limitations to the study design, as well as potential solutions, that could inform future studies. Larger studies, with more sites and participants, would allow for evaluation of the independent and interactive effects of IEQ attributes on employees' perceived health and well-being and productivity outcomes and for the use of triangulation methods to increase the credibility and validity of perceived employee outcomes.

We intend to continue surveying the respondents from these case studies in order to evaluate spring pre- and postmove perceived changes in asthma and allergies, monitor the Hawthorne effect as a potential source of bias in explaining improvements in employee productivity, and evaluate the annual real improvements in perceived employee outcomes to validate these preliminary findings. We will also conduct similar studies at more sites in order to contribute further empirical data to evaluate the hypothetical claims in the IEQ, health, and well-being literature. ■

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Contributors

All authors helped to design the study and survey instrument and write the article. A. Singh refined the survey instrument and supervised the collection of data and data analysis. M. Syal originated the study and led the development of the survey instrument, data collection, and analysis. S. Grady and S. Korkmaz participated in the data analysis.

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Human Participant Protection

This study was approved by the institutional review board of Michigan State University.

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