Neighborhood Environments and Physical Activity Among Adults in 11 Countries

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Background: Understanding environmental correlates of physical activity can inform policy changes. Surveys were conducted in 11 countries using the same self-report environmental variables and the International Physical Activity Questionnaire, allowing analyses with pooled data.

Methods: The participating countries were Belgium, Brazil, Canada, Colombia, China (Hong Kong), Japan, Lithuania, New Zealand, Norway, Sweden, and the U.S., with a combined sample of 11,541 adults living in cities. Samples were reasonably representative, and seasons of data collection were comparable. Participants indicated whether seven environmental attributes were present in their neighborhood. Outcomes were measures of whether health-related guidelines for physical activity were met. Data were collected in 2002–2003 and analyzed in 2007. Logistic regression analyses evaluated associations of physical activity with environmental attributes, adjusted for age, gender, and clustering within country.

Results: Five of seven environmental variables were significantly related to meeting physical activity guidelines, ranging from access to low-cost recreation facilities (OR=1.16) to sidewalks on most streets (OR=1.47). A graded association was observed, with the most activity–supportive neighborhoods having 100% higher rates of sufficient physical activity compared to those with no supportive attributes.

Conclusions: Results suggest neighborhoods built to support physical activity have a strong potential to contribute to increased physical activity. Designing neighborhoods to support physical activity can now be defined as an international public health issue.
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Introduction

The well-documented health burdens of physical inactivity have led national[1–3] and international[4,5] health agencies to prioritize physical activity promotion. Efforts to motivate and educate individuals can be complemented by creating social and built environments that make physical activity safe and convenient.[6] Authoritative groups found convincing evidence from a few developed countries that people are more active, especially for transportation, if they live in communities characterized by mixed land use (i.e., with stores in walking distance of homes); well-connected street networks; and high residential density than if they live in communities designed for automobile-dependent transportation with the opposite characteristics.[7,8] Other reviewers concluded that proximity to recreational facilities, along with pleasing aesthet-

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ics, was associated with more recreational physical activity.[9,10]

Limitations of the existing research examining associations between built environments and physical activity are apparent. First, the lack of experimental and prospective studies prevents conclusions about the direction of causality.[8] Second, specific characteristics of neighborhoods related to physical activity need to be identified to guide designers and planners to create more activity-friendly environments. Third, most studies examined subcomponents of physical activity, such as transportation or recreational activities, but the contribution of built environments to total physical activity, which should be most strongly related to health outcomes, has seldom been reported.[11–13] Finally, because studies have been conducted within single countries, limited environmental variability may lead to underestimation of true associations with physical activity. Such underestimation could reduce the apparent relevance of built-environment changes as physical activity promotion strategies.

The present study aimed to address all but the first limitation with a cross-sectional analysis of how neighborhood attributes in 11 countries help adults meet health-enhancing physical activity guidelines. The use of common methods and survey translation/adaptation protocols justified pooling across countries, creating a database with very wide variability in environments and populations.

Methods

International Physical Activity Prevalence Study (IPS)

The aim of the IPS was to collect nationally representative and internationally comparable prevalence estimates on physical activity from diverse countries. Interested investigators were required to show capacity and intent to follow rigorous guidelines to address known limitations in physical activity prevalence studies (i.e., seasonality, instrument translation and training, data coding, analysis strategy). As described elsewhere,[14] protocols for recruiting population samples and collecting data were established, with some allowances for modifications needed for local contexts. The sample was required to be representative of national populations or a significant region(s) within a country (defined as a population of >1,000,000), with an age range of 18–65 years. Households were typically selected at random, and individuals within households were selected either randomly or by most recent birthday.

Data collection in Spring or Fall 2002/2003 was required to reduce seasonal variations. If data were collected across 12 months, only Spring and Fall data were used, in most cases. Data were analyzed in 2007.

Of the 20 countries in which data were collected,[14] 11 completed an environmental survey: Belgium, Brazil, Canada, Colombia, China (Hong Kong), Japan, Lithuania, Norway, New Zealand, Sweden, and the U.S. Guidelines for survey translation and adaptation had to be followed (www.ipaq.ki.se), and translations of surveys back into English were approved.

Measure of Perceived Neighborhood Environment

Neighborhood attributes of relevance to physical activity were measured with seven items from the Physical Activity Neighborhood Environment Survey (PANES; also known as the IPS Environmental Module) that were used by all 11 countries (Appendix A, available online at www.ajpm-online.net; full survey available at www.ipaq.ki.se and www.drjamessallis.sdsu.edu). Most countries included additional items. Neighborhood was defined as the area within a 10- to 15-minute walk from home. Each item assessed an environmental attribute shown in previous studies to be related to physical activity for recreation[10] or transportation.[7,8,15] The main type of housing in neighborhoods (e.g., apartment, single-family) was used as an indicator of residential density. Having many stores within walking distance was used as an indicator of mixed land use. Access to a transit stop was included because transit use involves walking.[16] The presence of sidewalks and bicycling facilities was used to assess pedestrian and bicycling infrastructure. The presence of free or low-cost recreation facilities was assessed. Citing crime as a barrier to walking at night was used as an indicator of perceived crime, a social environmental variable.

With the exception of the item on the main type of housing, items were phrased as statements about an attribute of their neighborhood, with the following response options: strongly disagree, somewhat disagree, somewhat agree, strongly agree, don't know/not sure, or refused. For data analysis, responses were combined to create two levels: agree (strongly agree and somewhat agree) and disagree (strongly disagree and somewhat disagree). For types of housing, detached single-family (i.e., low-density) was compared to all others. Survey respondents (n=754) were excluded from data analysis if they selected responses of don't know/not sure or refused for any neighborhood-attribute item. Most items were taken or adapted from previously evaluated surveys of neighborhood environments.[13,17,18]

Test–retest reliability was evaluated in a separate sample of 135 adults recruited from neighborhoods that varied in income and walkability in Cincinnati OH, San Diego CA, and Boston MA. Intraclass correlations ranged from 0.64 for free or low-cost recreation facilities to 0.84 for sidewalks on most streets. Items had similarly high reliability in a Swedish study (except for perceived crime),[19] and reliability was also supported in a Nigerian sample.[20]

Neighborhood environment index. Analyses with individual environmental attributes indicated which items were most strongly related to physical activity. However, individual item results could not estimate the overall effect size of activity-friendly neighborhoods. A neighborhood environment index was constructed by summing the number of favorable "activity-friendly" environmental attributes. Preliminary analyses indicated that perceived crime, the only social environmental variable, reduced the Cronbach's alpha. Thus, the index was composed of the six built-environment items. Scores ranged from 0 to 6, with higher scores indicating a more favorable built environment for physical activity; Cronbach's alpha= 0.55. In the separate sample from three U.S. cities, the intraclass correlation (ICC) test–retest reliability for the sum

of the six items was ICC=0.86, with Cronbach's alpha=0.92. The difference in alpha coefficients may be a result of wider environmental variation in the international sample and the high education level of the U.S. reliability sample.

Physical Activity Measure

The short interviewer-administered International Physical Activity Questionnaire (IPAQ) measured the frequency and duration of walking, and moderate-intensity and vigorous physical activity, for leisure, transportation, and occupational purposes; and of inactivity (i.e., sitting) during the past week (except for Sweden, which used the self-administered format). For each question, respondents were given physiologic guidelines for breathing and heart rate, and country-specific examples of activities, to help them recall activities with an appropriate intensity level. Reliability and validity were evaluated with over 2500 adults from 12 countries.[21] One-week test–retest reliability of the short, interviewer-administered IPAQ was good (Spearman $r=0.70–0.97$). Criterion validity for the IPAQ total minutes per week was acceptable as measured against accelerometer total counts (Spearman $r=0.23$) and for the average correct classification of respondents accumulating ≥150 minutes per week of physical activity (Spearman $r=0.74$).[21]

Meeting guidelines for physical activity. The IPAQ was scored using the IPS scoring protocol (www.ipaq.ki.se) to classify participants as performing moderate amounts of physical activity, equivalent to meeting physical activity guidelines.[22,23] Meeting guidelines for moderate amounts of physical activity was defined by any of three criteria:

- ≥3 days of vigorous-intensity activity for at least 20 minutes per day;
- ≥5 days of moderate-intensity activity or walking for at least 30 minutes per day;
- ≥5 days of any combination of walking, or moderate- or vigorous-intensity activities, with a minimum of 600 MET-minutes per week.

A MET-minute is defined as the MET intensity multiplied by the minutes per week of activity. A MET is the activity metabolic rate divided by the resting metabolic rate, with one MET representing the energy expended while sitting quietly at rest. Intensity levels used to score the IPAQ were vigorous (8 METs), moderate (4 METs), and walking (3.3 METs).

Analyses

Data analyses were performed using SAS version 9.1. Data from each country were pooled and weighted to account for differential probabilities of sample selection and were post-stratified to the world 2001 population to facilitate comparisons among countries with varying age and gender distributions. Education could not be used as a covariate because it was missing for two countries. Descriptive characteristics of the analysis sample are presented unweighted for each country in Table 1; however, all additional analyses employed sample weights.

Neighborhood environmental variables have not been validated for rural residents and may not be relevant, so analyses were conducted among IPS participants living in towns or cities with populations ≥30,000. Prevalence of the seven environmental attributes was reported for each country. Odds of meeting guidelines for physical activity were modeled for each neighborhood environment item using the logistic regression program PROC LOGISTIC in SAS software. Models included age, gender, and country as covariates. Data were presented as ORs with 95% CIs. The strength of association between number of physical activity–supportive environmental attributes (the neighborhood environment index) and physical activity was examined using PROC LOGISTIC. The Wald statistic for the neighborhood index variable was interpreted as a test for a linear gradient and was considered significant at $p<0.05$.

Results

Description of Samples

About 70% of all participants (N=11,541) reported living in towns and cities with populations ≥30,000, ranging from 27.6% (Belgium) to 100% (Brazil, Colombia [Bogota], Hong Kong). Demographic characteristics of each country sample are shown in Table 1. Sample sizes ranged from 357 (Belgium) to 2674 (Colombia); genders were well balanced; and age distributions in the range of 20–64 years were generally balanced, except for that in Japan. Percentages of participants with >13 years of education ranged from <20% (Colombia) to >60% (Canada and the U.S.).

Table 2 shows substantial variation across countries in the percentage of participants who reported the presence of the seven built-environment characteristics. For example, having single-family homes as the main housing type varied from <1% (Hong Kong) to 88% (Brazil); sidewalk availability ranged from 25% (Brazil) to 97% (Hong Kong); and perceived lack of safety because of crime ranged from 16% (Canada and Norway) to almost 75% (Colombia and Lithuania).

Relationship Between Environmental Attributes and Meeting Health-Enhancing Physical Activity Guidelines

Seventy-seven percent of participants reported that they met guidelines for physical activity. As reported by Bauman and colleagues,[14] physical activity prevalence in the IPS is comparable to that found in other studies, especially a recent international study[24] using the short IPAQ. However, the IPAQ is known to demonstrate higher prevalence than other self-report surveys,[25–27] in part because IPAQ assesses all physical activity domains.

Physical activity prevalence was significantly related to five of the seven environmental variables (Figure 1): many shops nearby (OR=1.29 [95% CI=1.15, 1.44]); transit stop in neighborhood (OR=1.32 [95% CI=1.16, 1.54]); sidewalks on most streets (OR=1.47 [95% CI=1.32, 1.65]); bicycle facilities (OR=1.21 [95% CI=1.10, 1.33]); and low-cost recreational facilities (OR=1.16 [95% CI=1.05, 1.27]). All associations were in the expected direction, and only single-family homes and perceived crime were not significant.

Table 1. Unweighted sample characteristics of city (population ≥30,000) residents by country, *n* (%) unless otherwise indicated

Characteristic	Total sample *n* (%N)	Country				
		Belgium	Brazil	Canada	Colombia	Hong Kong
Total	11,541 (100)	357 (100)	876 (100)	619 (100)	2,674 (100)	990 (100)
Gender						
Male	5,129 (44.4)	208 (52.3)	433 (49.4)	314 (50.7)	1,083 (40.5)	466 (47.1)
Female	6,412 (55.6)	149 (41.7)	443 (50.6)	305 (49.3)	1,591 (59.5)	524 (52.9)
Age (years)						
18–29	3,665 (31.8)	38 (10.6)	330 (37.7)	143 (23.1)	1,052 (39.3)	186 (18.8)
30–39	2,894 (25.1)	79 (22.1)	227 (25.9)	152 (24.6)	668 (25.0)	271 (27.4)
40–49	2,512 (21.8)	103 (28.9)	174 (19.9)	165 (26.7)	517 (19.3)	305 (30.8)
50–65	2,470 (21.4)	137 (38.4)	145 (16.6)	159 (25.7)	437 (16.3)	228 (23.0)
Educational attainment						
≤13 years	5,625 (54.8)	—	—	200 (32.5)	2,174 (81.3)	769 (77.9)
>13 years	4,633 (45.2)	—	—	416 (67.5)	500 (18.7)	218 (22.1)
Meet guidelines by walking						
Yes	7,062 (61.2)	147 (41.2)	332 (37.9)	383 (61.9)	2,012 (75.2)	843 (85.2)
No	4,479 (38.8)	210 (58.8)	544 (62.1)	236 (38.1)	662 (27.8)	147 (14.9)
Meet guidelines for physical activity						
Yes	9,147 (79.3)	203 (56.9)	571 (65.2)	527 (85.1)	2,139 (80.0)	853 (86.2)
No	2,394 (20.7)	154 (43.1)	305 (34.8)	92 (14.9)	535 (20.0)	137 (13.8)

	Country					
	Japan	Lithuania	New Zealand	Norway	Sweden	U.S.
Total	442 (100)	1,291 (100)	803 (100)	492 (100)	434 (100)	2,563 (100)
Gender						
Male	281 (63.6)	508 (39.4)	318 (39.6)	237 (48.2)	194 (44.7)	1,087 (42.4)
Female	161 (36.4)	783 (60.7)	485 (60.4)	255 (51.8)	240 (55.3)	1,476 (57.6)
Age (years)						
18–29	356 (80.5)	538 (41.7)	190 (23.7)	128 (26.0)	111 (25.6)	593 (23.1)
30–39	86 (19.5)	255 (19.8)	227 (28.3)	128 (26.0)	116 (26.7)	685 (26.7)
40–49	—	268 (20.8)	185 (23.0)	107 (21.8)	80 (18.4)	608 (23.7)
50–65	—	230 (17.8)	201 (25.0)	129 (26.2)	127 (29.3)	677 (26.4)
Educational attainment						
≤13 years	248 (56.9)	498 (38.9)	464 (57.8)	196 (41.2)	237 (54.9)	839 (32.9)
>13 years	188 (43.1)	782 (61.1)	339 (42.2)	280 (58.8)	195 (45.1)	1,715 (67.2)
Meet guidelines by walking						
Yes	223 (50.5)	698 (54.1)	469 (58.4)	288 (58.5)	235 (54.2)	1,432 (55.9)
No	219 (49.5)	593 (45.9)	334 (41.6)	204 (41.5)	199 (45.9)	1,131 (44.1)
Meet guidelines for physical activity						
Yes	289 (65.4)	1,074 (83.2)	677 (84.3)	390 (79.3)	316 (72.8)	2,108 (82.3)
No	153 (34.6)	217 (16.8)	126 (15.7)	102 (20.7)	118 (27.2)	455 (17.8)

Strength of Association

The number of physical activity–supportive built-environment attributes was positively related to meeting guidelines for physical activity (Figure 2). The Wald statistic for the regression coefficient can be interpreted as a test for linear gradient; Wald χ^2=64.86, p<0.0001. There were significant differences in physical activity prevalence for those reporting four, five, or six attributes compared to those reporting zero, and the OR for six supportive attributes was 2.00.

Because education may confound the relation between physical activity and built-environment attributes, the analysis was repeated, covarying for education, using samples from the nine countries with education data. Only participants with all six favorable neighborhood environmental attributes were significantly more likely than those with zero favorable attributes to meet physical activity recommendations. For the score of six built-environment neighborhood attributes, the OR adjusting for education was 1.7 (95% CI=1.2, 2.4), whereas the original OR was 2.0 (95% CI=1.4, 2.8).

Discussion

Five of seven neighborhood environmental variables were significantly associated with meeting guidelines for physical activity in a study of 11 countries. There was evidence of a linear gradient in the relationship, such that the more supportive the reported built-environment attributes were for the neighborhood, the more likely the person was to be sufficiently physically active. Although adjusting for education reduced the associa-

Table 2. Weighted percentage of city residents, by country, who agree their neighborhood environment has given attributes

	Country										
Environmental variable	**Belgium** (n=357)	**Brazil** (n=876)	**Canada** (n=619)	**Colombia** (n=2674)	**Hong Kong** (n=990)	**Japan** (n=442)	**Lithuania** (n=1291)	**New Zealand** (n=803)	**Norway** (n=492)	**Sweden** (n=434)	**U.S.** (n=2563)
Single-family houses the main housing type	32.7	88.0	60.9	21.7	0.3	30.0	15.3	74.5	40.6	28.1	60.8
Many shops within walking distance	62.1	85.2	69.0	93.2	88.4	83.2	82.5	74.8	84.1	78.2	59.6
Transit stop within 10–15 minutes from home	74.1	94.8	82.8	96.5	96.4	91.0	91.1	92.1	97.4	97.2	68.0
Sidewalks on most streets	83.9	25.2	77.2	91.1	96.9	59.1	86.7	94.6	76.5	95.7	73.9
Facilities to bicycle in or near neighborhood	78.5	33.9	67.9	45.4	37.2	24.8	47.6	45.7	72.0	78.7	57.4
Low-cost recreation facilities	78.8	28.3	87.3	50.9	72.9	59.8	54.5	87.0	75.1	78.8	69.8
Crime rate makes it unsafe to walk at night	24.3	65.5	16.1	74.8	36.3	32.9	74.6	39.4	16.3	39.3	31.5

Note: Sample consists of those who reported living in cities with populations ≥30,000.

tion somewhat, having many favorable neighborhood environmental characteristics remained positively associated with physical activity. The present results demonstrate that previous findings linking neighborhood environments with physical activity, based on studies in a few developed countries, can be generalized to a broad range of countries. Designing neighborhoods to support physical activity can now be defined as an international public health issue.

The environmental attribute with the highest OR was having sidewalks on most streets in the neighborhood. This finding may reflect the fact that sidewalks can be used for many common types of physical activity, including walking, jogging, and skating, for both recreation and transportation purposes. Ensuring access to sidewalks may be a practical and effective policy for encouraging physical activity.

The hypothesis that a cluster of activity-friendly attributes would be needed to support higher rates of meeting physical activity guidelines was supported. Although single attributes were associated with 15%–50% higher rates of meeting guidelines, when all six built-environment attributes were present, rates of physical activity were 100% higher, compared to those in neighborhoods with no supportive attributes. After adjusting for education in an analysis of nine countries, the OR was still a significant 1.7. These strong associations contrast with reports that neighborhood environments had weak associations with physical activity.[28–30] Including the full range of environmental variation across countries likely accounts for the stronger associations found in the current study.

The multiple significant individual variables suggest that a variety of environmental interventions may affect physical activity, with different environmental variables having particular relevance for physical activity for transportation versus recreation purposes.[31,32] There is substantial interest in crime as a barrier to physical activity, but studies to date have produced inconsistent results regarding this variable,[10,33] and the association was not significant in the present study. More sophisticated measures of crime and domain-specific measures of physical activity are needed to further explore this important topic. All other significant associations with physical activity were consistent with previous findings,[7,8,10,16,34] except for the lack of association with residential density in the current study.

The perceived built-environment items may be useful for environmental surveillance because they revealed substantial variation by country, and the associations with physical activity supported the construct validity of the items. Each country had a unique profile on this set of items (Table 2). Hong Kong appeared to have the most "activity-friendly" built environment on most items, but bicycling facilities were available to few residents.

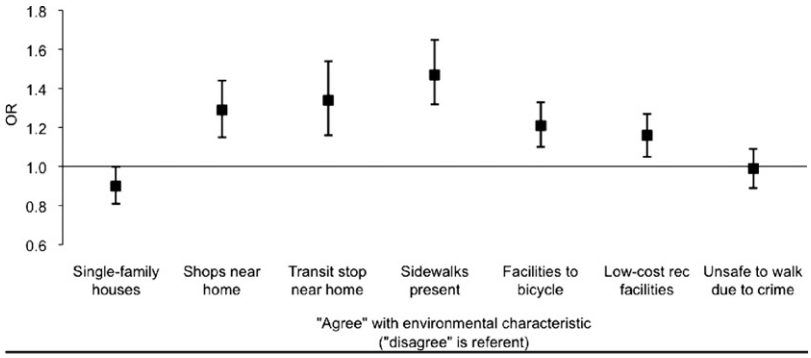

Figure 1. Results of logistic regression analysis of the relationship of seven perceived neighborhood attributes to meeting physical activity guidelines among city residents only, adjusted for gender, age, and country (pooled sample N=11,541)

The U.S. had the most limited access to transit stops and was the only country in which less than 60% of participants were within walking distance of shops. These findings help explain the small percentage of trips made by walking and bicycling in the U.S.[8] Although the U.S. has one of the highest violent crime rates in the world,[35] the perceived level of crime was lower than that in Lithuania, Colombia, and Brazil. The majority of participants in all countries except Brazil reported having free or low-cost recreation facilities and sidewalks on most streets in their neighborhoods. European countries had the highest access to bicycling facilities.

Strengths of the study include the assessment of large samples of adults in 11 countries using standardized methods. Participating countries provided broad geographic and sociopolitical diversity, including five continents and some developing nations. Survey items had evidence of good test–retest reliability in multiple countries. Authoritative guidelines[22,23] were used as the criteria for health-enhancing physical activity. However, there were challenges to conducting a multi-country study. Despite efforts to standardize and adapt the survey items, interpretations and meanings of items could vary by country, especially on subjective items such as perception of crime. The number of environmental variables was limited by the multipurpose survey, so each concept was measured by a single item. The short IPAQ did not provide data on specific domains of physical activity (e.g., transportation, recreation) that may have produced stronger associations with neighborhood characteristics.[31,36] The IPAQ has been shown to overestimate physical activity,[25–27,37] so actual prevalence rates are likely not as high as those reported here. Reliability and validity for IPAQ appear to vary by the country's level of development.[21] The cross-sectional design does not allow interpretations about direction of effect, so self-selection of active people into activity-friendly neighborhoods remains a possibility.[8] Inclusion of people in cities with populations ≥30,000 could be considered a limitation, but the assessed built-environment attributes were not expected to be relevant for rural areas. Reports of environmental attributes could be biased if more active people perceive their environments differently than do inactive people.

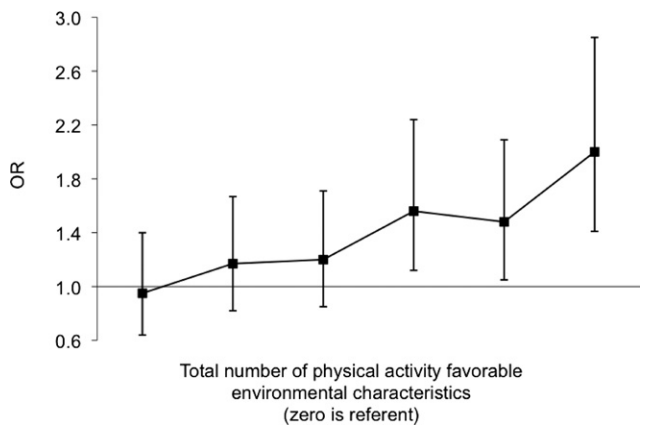

Figure 2. Association between number of physical activity–favorable built-environment attributes and meeting physical activity guidelines among city residents only, adjusted for gender, age, and country (pooled sample N=11,541)

Previous within-country findings that neighborhood environments are related to physical activity[7,8,10,15,31,34] were replicated and extended in the present international study. A variety of neighborhood attributes relevant to physical activity for both the transportation and recreation domains were associated with meeting health-enhancing guidelines. These findings suggest that changes to the built environment may be effective in increasing physical activity, but multiple environmental changes are likely needed to have a substantial effect. Prospective and experimental studies are required to strengthen evidence of causality. In the present study, highly supportive environments were associated with a 100% higher likelihood of sufficient physical activity and with a 70% higher likelihood of meeting guidelines after adjusting for education. These are large effects for a potential intervention, and they are expected to be relatively permanent. Each country had a unique profile of environmental supports, so population surveys of neighborhood characteristics can be used for environmental surveillance.

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Appendix

Supplementary Data

Supplementary data associated with this article can be found in the online version, at doi:10.1016/j.amepre.2009.01.031.