Neighborhood Disadvantage and Physical Activity: Baseline Results from the HABITAT Multilevel Longitudinal Study

Turrell, Gavin; Haynes, Michele; Burton, Nicola W.; Giles-Corti, Billie; Oldenburg, Brian; Wilson, Lee Ann; Giskes, Katrina; Brown, Wendy J.

Published in:
Annals of Epidemiology

DOI:
10.1016/j.annepidem.2009.11.004

Title: Neighborhood disadvantage and physical activity: baseline results from the HABITAT multilevel longitudinal study

Authors

Gavin Turrell, PhD (first and corresponding author)

School of Public Health, Queensland University of Technology, Victoria Park Road, Kelvin Grove, Brisbane, Queensland, Australia, 4059. Tel: 61-7-31388285, Fax 61-7-31383130, email g.turrell@qut.edu.au.

Michele Haynes, PhD

Nicola W Burton, PhD

Billie Giles-Corti, PhD

Brian Oldenburg, PhD

Lee-Ann Wilson, BA

Katrina Giskes, PhD

Wendy J Brown, PhD

Running title: Neighborhood disadvantage and physical activity

Abstract word count: 270

Text word count: 4143

Number of tables: 6

Number of figures: 0

PURPOSE: To examine the association between neighborhood disadvantage and physical activity (PA).

METHODS: We use data from the HABITAT multilevel longitudinal study of PA among mid-aged (40-65 years) men and women (n=11, 037, 68.5% response rate) living in 200 neighborhoods in Brisbane, Australia. PA was measured using three questions from the Active Australia Survey (general walking, moderate, and vigorous activity), one indicator of total activity, and two questions about walking and cycling for transport. The PA measures were operationalized using multiple categories based on time and estimated energy expenditure that were interpretable with reference to the latest PA recommendations. The association between neighborhood disadvantage and PA was examined using multilevel multinomial logistic regression and Markov Chain Monte Carlo simulation. The contribution of neighborhood disadvantage to between-neighborhood variation in PA was assessed using the 80% interval odds ratio.

RESULTS: After adjustment for sex, age, living arrangement, education, occupation, and household income, reported participation in all measures and levels of PA varied significantly across Brisbane's neighborhoods, and neighborhood disadvantage accounted for some of this variation. Residents of advantaged neighborhoods reported significantly higher levels of total activity, general walking, moderate, and vigorous activity; however, they were less likely to walk for transport. There was no statistically significant association between neighborhood disadvantage and cycling for transport. In terms of total PA, residents of advantaged neighborhoods were more likely to exceed PA recommendations.

CONCLUSIONS: Neighborhoods may exert a contextual effect on residents' likelihood of participating in PA. The greater propensity of residents in advantaged neighborhoods to do high levels of total PA may contribute to lower rates of cardiovascular disease and obesity in these areas.

MeSH words: Markov Chains, Multilevel Analysis, Neighborhood, Physical Activity, Socioeconomic Factors

List of abbreviations and acronyms

BMI:	Body Mass Index
CCD:	Census Collectors District
CVD:	Cardiovascular disease
IRSD:	Index of Relative Socioeconomic Disadvantage
MCMC:	Markov chain Monte Carlo
PA:	Physical activity
SES:	Socioeconomic status

Numerous multilevel studies have examined the relationship between neighborhood disadvantage and health (1-3) and much of this work shows that residents of disadvantaged areas have significantly higher levels of mortality for chronic conditions such as cardiovascular disease (CVD) (4-6) and for related risk factors such as overweight and obesity (7-9).This present paper adds to our understanding of these health inequalities by focusing on the association between neighborhood disadvantage and physical activity (PA). PA is related to numerous chronic conditions (10) including CVD (11, 12) and obesity (13, 14) hence differences in the prevalence of these conditions between advantaged and disadvantaged neighborhoods may partly reflect concomitant differences in activity.

Eight multilevel studies were identified that had examined the association between neighborhood disadvantage and PA (15-22). Residents of disadvantaged neighborhoods tended to have lower levels of total and leisure time PA, but were more likely to engage in activity for utilitarian purposes such as walking or cycling for transport. A large body of research has shown that numerous environmental characteristics of neighborhoods promote, support, or limit opportunities for leisure-time and transport-related activity (23-27). Accordingly, differences between advantaged and disadvantaged neighborhoods in these factors may contribute to differences in PA. Differences in leisure-time activity might reflect concomitant differences in the availability and accessibility of recreational facilities (e.g. gyms, parks), the extent of green space, levels of crime and incivilities (e.g. litter and graffiti), and the provision of streets with sidewalks, low volumes of traffic, and adequate lighting. Neighborhood differences in transport-related activity might reflect concomitant differences in street connectivity, residential density, proximity to destinations (e.g. shops, services), and access to public transport.

Multilevel studies investigating the association between neighborhood disadvantage and PA have typically operationalized PA using broad qualitative categories (e.g. none/some), or frequency-based indicators (e.g. days per week) or dichotomous measures (e.g. yes/no). These types of measures obscure a fuller understanding of neighborhood disadvantage and PA as they provide little information about the quantity of activity, hence detailed analysis of activity patterns or dose-response relationships are not possible. In addition, the qualitative nature of the measurement doesn't allow the data to be examined and/or interpreted with reference to PA recommendations. We redress these limitations by using four generic (general walking, moderate, vigorous and total activity) and two specific (walking and cycling for transport) quantitative measures of PA that are based on time (minutes/week) and estimated energy expenditure (MET.minutes/week). Moreover, each of the six measures is operationalized using multiple sensitive levels that comprise categories that can be meaningfully interpreted with reference to the latest PA recommendations (28).

The relationship between neighborhood disadvantage and PA has been investigated primarily on the basis of multilevel (binomial) logistic regression, which is appropriate given that most studies have used dichotomous measures of PA. In this paper, we employ multilevel multinomial logistic regression as five of our PA measures are polytomous. Importantly, the application of multinomial modeling allows us to assess whether the magnitude of the association between neighborhood disadvantage and PA is the same or different at low, moderate, and high levels of activity. Further, a recent critical review of multilevel studies investigating neighborhood effects on health observed that multilevel analyses are often applied sub-optimally (3) because they typically only present findings for fixed (average) effects and underutilize the explanatory potential of the random variance which captures the size of the difference between neighborhoods in the health outcome being examined (29-31). This critique is applicable to multilevel investigations of neighborhood disadvantage and PA where the emphasis to date has been almost exclusively on the fixed effects. In this paper, we focus on both fixed- and random-effects as the latter enables us to quantify the extent of between-neighborhood variation in PA and then estimate the contribution of neighborhood disadvantage to this variation.

This investigation uses baseline data from the HABITAT (**H**ow **A**reas in **B**risbane **I**nfluence Heal**T**h and **A**c**T**ivity) study. HABITAT is a multilevel longitudinal (2007-2011) study of PA among mid-aged (40 – 65 years) adults living in Brisbane, Australia. In the present analyses we examine three interrelated questions:

1. Do neighborhoods vary in their average rates (probabilities) of PA?

2. Does neighborhood disadvantage contribute to any observed between-neighborhood variation in PA?
3. What is the relationship between neighborhood disadvantage and PA, and do neighborhoods exert a contextual effect on people's likelihood of engaging in PA?

METHODS

The HABITAT study was awarded ethical clearance by the Queensland University of Technology Human Research Ethics Committee (Ref. No. 3967H).

Sample Design

Details about HABITAT's sampling design have been published elsewhere (32). Briefly, a multi-stage probability sampling design was used to select a stratified random sample (n=200) of Census Collector's Districts (CCD), and from within each CCD, a random sample of people aged 40-65 years (n=17,000).

Data Collection and Response Rates

A structured self-administered questionnaire was developed (33, 34) that asked respondents about their neighborhood, participation in PA, correlates of activity, and socio-demographic characteristics. The questionnaire was administered during May-July 2007 using a mail-survey method (35) and a total of 11,037 usable surveys were returned (response rate 68.5%).

Measures

Neighborhood disadvantage: Each of the 200 CCDs was assigned a socioeconomic score using the Australian Bureau of Statistics' (ABS) Index of Relative Socioeconomic Disadvantage (IRSD) (36). The IRSD scores were calculated using 2006 census data and derived by the ABS using Principal Components Analysis. A CCDs IRSD score reflects each area's overall level of disadvantage measured on the basis of 17 variables that capture a wide range of socioeconomic attributes, including; education, occupation, income, unemployment, household structure, household tenure, marital status, English language competency, motor vehicle availability, and Indigenous status. For analysis, the 200 CCDs were grouped into quintiles based on their IRSD scores with Q1 denoting the 20% (n=40) most disadvantaged areas in Brisbane and Q5 the least disadvantaged 20% (n=40). The socioeconomic profile of these quintiles is presented in Table 1.

TABLE 1

Physical activity: This was measured using three questions from the Active Australia Survey (37), one indicator of total activity, and two questions that specifically asked about walking and cycling for transport. The Active Australia questions (which assess walking, moderate, and vigorous activity) are generic in that they do not explicitly ask the respondent to differentiate between the various sources of activity (e.g. leisure, transport, occupational); however, anecdotal evidence from our other PA studies suggests that most people answer the Active Australia questions with reference to PA for leisure, recreation, or exercise. The Active Australia questions have demonstrated reliability and validity (38, 39) and are recommended for use in Australian population-based research (40).

(i) General walking: respondents estimated the total time spent walking "continuously for 10 minutes" in the previous week for "recreation, exercise, or to get to or from places". Minutes walking were categorized as: None/negligible (<30mins), very low (≥30 <90mins), low (≥90 <150mins), moderate (≥150 <300mins) and high (>300mins).

(ii) Vigorous activity: respondents estimated the total time in the previous week spent doing any vigorous PA (excluding household chores, gardening or yard work) that "made you breathe harder or puff or pant" such as jogging, cycling, or aerobics. Minutes of vigorous activity was categorized as: low (<60mins), moderate (≥60 <120mins), high (≥120 <240mins), and very high (>240mins).

(iii) Moderate activity: respondents estimated the total time in the previous week spent doing moderate physical activities (excluding household chores, gardening or yard work) "that you have not already mentioned" such as gentle swimming, social tennis, or golf. Minutes of moderate activity was categorized into five levels as for walking.

(iv) Total PA was measured in MET.minutes/week as an estimate of energy expenditure. This was calculated as [walking minutes * 4METS] + [moderate minutes * 4 METS] + [vigorous minutes * 7.5 METS]). Total activity was categorized as: none/negligible (<90), very low (≥90 <270), low (≥270 <450), moderate (≥450 <900), high (≥900 <1,800) and very high (≥1,800). The 'moderate' category for this measure corresponds to current PA recommendations for the promotion and maintenance of health among adults aged 18-65 years (28).

(v) Walking for transport: respondents estimated the total time spent walking for transport in the previous week and this was categorized as: none (≥1 <60mins), moderate (≥60 <150 mins), and high (≥150 mins).

(vi) Cycling for transport: respondents estimated the total time spent cycling for transport in the previous week and this was categorized as none (0) and any (>0 mins).

Controls: The IRSD is an ecologic exposure derived by aggregating individual responses to questions asked on the national census form. When testing for an ecologic effect with an aggregated exposure it is necessary to simultaneously model individual-level variables (e.g. income) and their neighborhood-level analogues (e.g. % low income households) (41). To this end, we included four individual-level controls in the multilevel analyses – living arrangement, education, occupation, and household income – each of which has an area-level analogue represented in the IRSD. Sex and age were also included as controls. Table 2 presents descriptive statistics for the IRSD measure and the control variables for the HABITAT sample, and compares these with the Brisbane population aged 40-65 years using 2006 census data. The sample is broadly representative of the wider population, although residents from disadvantaged areas, blue-collar employees, and persons who did not attain post-school educational qualifications are under-represented.

TABLE 2

Analysis

The small number of respondents who had missing data on current living arrangement (n=144, 1.3%) or education (n=47, 0.4%) were excluded, but those with missing data for occupation (n=910, 8.2%)

or household income (n=1,631, 14.8%) were retained. Respondents who did not answer any Active Australia questions (n=369, 3.3%) and/or questions on walking (n=194, 1.8%) or cycling (n=238, 2.2%) for transport were also excluded. This reduced the analytic sample to n=10,494 for the Active Australia questions (95.1% of the total sample) and n=10,745 (97.4%) and n=10,702 (97.0%) for walking and cycling for transport respectively.

General walking, moderate, vigorous, and total activity, and walking for transport, were defined by ordered categories, and preliminary analyses of these multinomial outcomes showed that the assumptions of the parallel slopes model were violated, particularly for neighborhood disadvantage (42). Hence the relationship between neighborhood disadvantage and each of these outcomes was modeled using multilevel multinomial unordered logistic regression. Cycling for transport was examined using a standard binary logit model.

When estimating the random parameters for these models (i.e. the between-neighborhood variance in PA) we used Marko Chain Monte Carlo (MCMC) simulation: this procedure was implemented using the Metropolis-Hastings algorithm via *MLwiN* software (43) with standard non-informative prior distributions on all parameters. To achieve convergence of the simulated chains for the variance parameters (assessed using the Raftery-Lewis and Brooks-Draper diagnostics) the Metropolis-Hastings algorithm was implemented for 150,000 iterations.

A three-stage modeling approach was used. Model 1 includes a random intercept only and does not condition on any other factor; Model 2 controls for within-neighborhood variation in age, sex, household-type, education, occupation and household income; and Model 3 further adjusts for neighborhood disadvantage. The fixed-effect estimates for each of the quintiles of neighborhood disadvantage derived from Model 3 were used to examine the association between neighborhood disadvantage and PA. Quintile 1 (i.e. the most disadvantaged neighborhoods) was used as the reference category and the results are reported as odds ratios (OR) and their 95% credible intervals (CrI). To quantify the fixed-effect contribution of neighborhood-level disadvantage to between-neighborhood variation in PA we used the 80% Interval Odds Ratio (IOR-80) (29, 44, 45).

RESULTS

Table 3 presents the PA profile of the HABITAT sample. Just over one third of respondents (36.7%) reported doing less than the recommended ≤450 MET.mins of total PA in the previous week. The majority of respondents (64.1%) did less than 150 minutes of general walking, less than 150 minutes of moderate activity (81.4%), and less than 60 minutes of vigorous activity (59.8%) in the previous week. The majority of the sample reported doing no walking (65.0%) or cycling (96.2%) for transport in the previous week.

TABLE 3

Table 4 presents the posterior mean estimates of the between-neighborhood variance in PA, along with the standard errors of the posterior distributions. These estimates reflect the extent to which the PA levels of the 200 neighborhoods vary around the overall mean level of PA for all neighborhoods in Brisbane. Prior to adjustment for any other factor (Model 1) total MET.minutes of activity varied significantly between neighborhoods. For example, 12.1% of the Brisbane population aged 40-65 years was classified as doing very low (≥90<270 MET.minutes) levels of total PA in the previous week (Table 3); however, this average rate differed significantly between the neighborhoods (neighborhood variance 0.161, se 0.038, p≤0.001). Statistically significant between-neighborhood variation was observed for each of the other levels of total PA, and for all other measures of activity. Moreover, with the exception of moderate activity, there was a linear gradient between the magnitude of the neighborhood variation and the PA level: neighborhood variation was smallest for the lowest PA level, intermediate for the mid-range levels, and largest for the highest levels of PA. After adjustment for age, sex, living arrangement, education, occupation, and household income (Model 2) the between-neighborhood variation in PA was reduced by 5%-45.2%; however, statistically significant between-neighborhood variation remained for all measures of activity. Adjustment for neighborhood disadvantage (Model 3) further reduced the neighborhood variation in PA for most levels of each measure, although statistically significant between-neighborhood variation was still evident. In this fully adjusted model, neighborhood variation in PA was largest at the highest level of activity for all measures except moderate activity.

TABLE 4

Table 5 presents 80% IORs: these quantify the contribution of neighborhood-level disadvantage to the overall between-neighborhood variation in PA. Given the large amount of data, interpretation is made with reference to two contrasting scenarios. First, the IOR-80 for Q1 and Q5 comparing negligible versus very high levels of total PA is 1.23-3.37: if we randomly selected residents with identical individual-level characteristics from Q1 and Q5 and compared their odds of doing very high levels of total PA, the middle 80% of the ORs will lie within this interval. The interval does not contain 1, thus differences in neighborhood disadvantage between Q1 and Q5 accounts for a substantial amount of the overall between-neighborhood variation in the propensity to do very high levels of total PA. However, the interval is of moderate width, which indicates that a sizeable amount of the between-neighborhood variation in very high levels of total PA remains unexplained. Second, the IORs for Q1 and Q2 comparing none versus high levels of walking for transport is 0.37-1.89. This interval contains 1, hence differences in neighborhood disadvantage between Q1 and Q2 do not account for much of the of the overall between-neighborhood variation in this type and level of activity. Moreover, the interval-range is broad, thus a substantial proportion of the between-neighborhood variation in walking for transport at high levels is left unexplained.

TABLE 5

Table 6 examines the fixed-effect association between neighborhood disadvantage and PA after adjustment for compositional factors. Given the large number of potentially reportable findings, only a single (select) association is described for each measure of PA. The probability of doing high (versus negligible) levels of total PA for residents living in neighborhoods in Q5 was 78% higher (OR 1.78, 95% CrI 1.34-2.38) than residents living in neighborhoods in Q1. The probability of residents in Q5 doing high levels of general walking (versus negligible) was 50% higher (OR 1.50, 95% CrI 1.12-2.04) than their counterparts in neighborhoods in Q1. Residents living in neighborhoods in Q5 had a 72% greater likelihood (OR 1.72, 95% CrI 1.23-2.40) of doing high levels of moderate PA (versus negligible) compared with residents living in neighborhoods in Q1. The probability of doing very high levels of vigorous PA (versus low levels) for residents living in neighborhoods in Q5 was 75% higher (OR 1.75, 95% CrI 1.36-2.27) than residents in the most disadvantaged neighborhoods (Q1). Notably, the magnitude of the association between neighborhood disadvantage and PA for each of the aforementioned PA measures was different for low and high levels of activity. For example, residents in neighborhoods in Q5 (relative to Q1) were 27% more likely to do very low (versus negligible) levels of total activity, whereas the corresponding difference between Q5 and Q1 for very high levels of total activity (versus negligible) was 103%. A similar pattern is evident for walking, moderate, and vigorous activity. The probability of residents in neighborhoods in Q5 doing high levels of walking for transport (versus none) was 35% lower (OR 0.65, 95% CrI 0.44-0.97) than residents in neighborhoods in Q1. There was no statistically significant association between neighborhood disadvantage and cycling for transport.

TABLE 6

DISCUSSION

Neighborhood variation in physical activity

Participation in PA varied significantly across Brisbane neighborhoods: this was evident for total PA, general walking, moderate and vigorous activity, and walking and cycling for transport. Moreover, for each of these measures we observed statistically significant variation between neighborhoods for all levels of activity. Adjustment for sex, age, living arrangement, education, occupation, and household income accounted for a substantial proportion (5.0%-45.2%) of the between-neighborhood variation in PA: this outcome adds further support to the now large body of research showing that household- and individual-level demographic and socioeconomic factors are important determinants of PA (46, 47). For general walking, vigorous activity, and walking for transport, the between-neighborhood variation in PA tended to be smallest at the lower levels of activity and largest at the higher levels. The reasons for this are unclear; possibly, neighborhoods in Brisbane do not differ greatly on the physical, social, or cultural characteristics that promote or dissuade lower levels of PA, whereas neighborhood-level variation might be much greater for those environmental factors that influence high levels of PA.

Neighborhood disadvantage accounted for nil-to-moderate amounts (0.0%-24.1%) of the between neighborhood variation in PA. The IOR-80 however indicated that the contribution of neighborhood disadvantage was limited to socioeconomic differences between the most and least disadvantaged neighborhoods (i.e. Q1 & Q5, Q1 & Q4); there was no evidence, for example, that socioeconomic differences between the bottom two quintiles (i.e. Q1 & Q2) made an important contribution to the between neighborhood variation in PA. In addition, neighborhood disadvantage only made a substantial contribution to the between-neighborhood variation for specific levels of total activity, moderate, and vigorous activity. Notably, even after adjustment for household- and individual-level compositional factors and neighborhood disadvantage, statistically significant between-neighborhood variation remained for all measures and levels of PA, indicating that Brisbane's neighborhoods are differentiated on other (unmeasured) neighborhood-level factors that influence PA.

Neighborhood disadvantage and physical activity

Independent of compositional factors, residents of the least disadvantaged neighborhoods (Q4 and Q5) were significantly more likely than their counterparts in the most disadvantaged neighborhoods (Q1) to have reported doing high/very high levels of total PA, high levels of general walking and moderate PA, and high/very high levels of vigorous activity. These findings suggest that neighborhoods in Brisbane may exert a contextual effect on residents' likelihood of participating in PA, and they broadly concur with the results of previous multilevel studies of neighborhood disadvantage and PA (15-22). Direct comparison with earlier multilevel research however is not possible, as these studies typically measured PA using qualitative categories that were operationalized as dichotomies. The findings of this study also showed that for total PA, general walking, moderate, and vigorous activity, the magnitude of the association between neighborhood disadvantage and PA differed across the levels of activity.

In terms of total PA, residents of advantaged neighborhoods were more likely to be meeting the current (2007) American College of Sports Medicine (ACSM) and the American Heart

Association PA recommendations (28). Importantly, we found that residents of advantaged neighborhoods were more likely to undertake total PA at levels well beyond this recommended level. Multilevel studies of CVD and BMI show that residents of advantaged neighborhoods have a lower risk of CVD incidence and mortality (4-6) and are less likely to be overweight or obese (7-9). Arguably this is because residents of advantaged neighborhoods do PA at levels that offer greater cardio-protective and weight maintaining benefits.

Of the PA measures, vigorous activity is perhaps the least ambiguous and easiest to recall in terms of participation. Respondents are asked to report the time spent doing activities that noticeably raise the heart rate and breathing (e.g. jogging, aerobics, competitive tennis): hence vigorous activity probably contains the smallest amount of measurement error and has the greatest capacity to differentiate neighborhood differences. Consistent with the findings of other Australian (18, 46) and overseas studies (19) residents of advantaged neighborhoods in Brisbane were significantly more likely to participate in vigorous activity.

Both walking and cycling can be undertaken for exercise, recreation or transportation. Studies that differentiate walking and cycling on these dimensions find that residents of advantaged neighborhoods are more likely to walk (19, 28, 48) and cycle (22) for exercise or recreation and less likely to do so for transport. Studies of cycling that fail to differentiate between recreation and transport find no association with neighborhood disadvantage (18). In this present study, respondents were first asked about walking in general and separately about walking for transport. Residents of advantaged neighborhoods reported doing more general walking, although this was only significant for the highest level. This somewhat modest and inconsistent finding was possibly due to the non-specificity of the general walking question: because the question encapsulates two types of walking with opposite socioeconomic effects, the association between neighborhood disadvantage and general walking was biased towards the null. By contrast, the results for walking for transport showed very clear socioeconomic effects, with residents of advantaged neighborhoods being significantly less likely to walk for utilitarian purposes. Residents of advantaged neighborhoods were also less likely to have reported cycling for transport; however, this association didn't reach statistical significance due to insufficient power.

Study Limitations

Survey non-response in the HABITAT baseline study was 31.5%, and non-response tended to be higher among the low SES. If these non-responding low SES residents were also less likely to participate in PA, then the socioeconomic differences in PA reported in this paper are likely to be an underestimate of the 'true' magnitude of socioeconomic differences in the Brisbane population.

Our use of a CCD to represent a neighborhood was motivated by sampling and analytic convenience rather than being informed by theory linking the neighborhood context with PA (57). This 'pragmatic' definition of a neighborhood is unlikely to capture the lived-reality and complexity of the neighborhood environment (50) hence the associations between neighborhood disadvantage and activity reported in this paper are likely to have been underestimated.

We reported cross-sectional evidence hence no claims about causality can be made. Additionally, our use of an index of neighborhood disadvantage provides no direct assessment of the features of the neighborhood that are important for PA, nor does it allow us to identify the factors that differentiate advantaged and disadvantaged neighborhoods in term of their patterns and levels of activity.

Conclusions

This paper has offered new and important insights into the patterning of PA in the population and has added to our understanding of the relationship between neighborhood disadvantage and PA. These contributions were made possible in part by measuring PA using multiple sensitive categories that could be interpreted with reference to the latest PA recommendations. These measures were then analyzed using multilevel multinomial logistic regression, which included applying MCMC simulation to estimate the random parameters (i.e. the between-neighborhood variation in PA) and then quantifying the effect of neighborhood disadvantage on this variation using the interval odds ratio. Arguably, these types of advances in the measurement of PA, in conjunction with a more optimal and sophisticated use of multilevel methods and analyses, are a necessary basis for furthering knowledge about *why* residents of advantaged and disadvantaged neighborhoods differ in their PA.

Our results indicate that neighborhood-, household-, and individual-level factors each make a contribution to PA participation, which provides support for the notion that policies and interventions to increase levels of activity in the population should focus on places, people, and their interactions (51, 52). At this stage however, the exact form and content of these policies and interventions remains somewhat unclear, hence there is a need for future research to investigate the aspects of advantaged and disadvantaged neighborhoods that give rise to their different levels and patterns of PA. Moreover, our findings add further support for the adoption of a social-ecological perspective in advancing knowledge of the determinants of PA (53, 54).

The fact that the patterning of PA for recreation and transport varies by neighborhood disadvantage underscores the need for greater specificity in the measurement of PA and its determinants (55). Finally, levels of PA are not inevitably lower in socioeconomically disadvantaged neighborhoods. Higher levels of walking and cycling for transport in disadvantaged neighborhoods are likely to confer health benefits to the residents and hence minimize neighborhood inequalities in chronic disease and related risk factors such as obesity (56, 57). Neighborhood-level intervention efforts that facilitate and support walking and cycling for transport should therefore be promoted (46).

Acknowledgements

The HABITAT study is supported by project grants from the National Health and Medical Research Council (NHMRC) (Nos. 339718, 497236). GT and BGC are supported by NHMRC Senior Research Fellowships (Nos: 390109 & 503712 respectively) and NB is supported by a Heart Foundation Research Fellowship (No: PH08B3905) and an NHMRC Capacity Building Grant (No: 252977). We gratefully acknowledge Mr Martin O'Flaherty for his assistance with data coding and cleaning and Ms Robyn Baguley for her work as Project Manager on HABITAT.

References

1. Kawachi I, Berkman LF, eds. *Neighborhoods and Health*. New York: Oxford University Press; 2003.
2. Pickett KE, Pearl M. Multilevel analyses of neighbourhood socioeconomic context and health outcomes: a critical review. *J Epidemiol Community Health* 2001;55(2):111-122.
3. Riva M, Gauvin L, Barnett TA. Toward the next generation of research into small area effects on health: a synthesis of multilevel investigations published since July 1998. *J Epidemiol Community Health* 2007;61(10):853-861.
4. Diez Roux AV, Merkin SS, Arnett D, et al. Neighborhood of residence and incidence of coronary heart disease. *N Engl J Med* 2001;345(2):99-106.
5. Dragano N, Bobak M, Wege N, et al. Neighbourhood socioeconomic status and cardiovascular risk factors: a multilevel analysis of nine cities in the Czech Republic and Germany. *BMC Public Health* 2007;7:255.
6. Chaix B. Geographic life environments and coronary heart disease: a literature review, theoretical contributions, methodological updates, and a research agenda. *Annu Rev Public Health* 2009;30:81-105.
7. King T, Kavanagh A, Jolley D, et al. Weight and place: a multilevel cross-sectional survey of area-level social disadvantage and overweight /obesity in Australia. *Int J Obes* 2006;30:281-287.
8. van Lenthe F, Mackenbach J. Neighbourhood deprivation and overweight: the GLOBE study. *Int J Obes* 2002;26:234-240.
9. Matheson FI, Moineddin R, Glazier RH. The weight of place: a multilevel analysis of gender, neighborhood material deprivation, and body mass index among Canadian adults. *Soc Sci Med* 2008;66(3):675-690.
10. Schnohr P, Scharling H, Jensen JS. Changes in leisure-time physical activity and risk of death: an observational study of 7,000 men and women. *Am J Epidemiol* 2003;158(7):639-644.

11. Wannamethee SG, Shaper AG, Walker M. Changes in physical activity, mortality, and incidence of coronary heart disease in older men. *Lancet* 1998;351(9116):1603-1608.

12. Manson JE, Greenland P, LaCroix AZ, et al. Walking compared with vigorous exercise for the prevention of cardiovascular events in women. *N Engl J Med* 2002;347(10):716-725.

13. Besson H, Ekelund U, Luan J, et al. A cross-sectional analysis of physical activity and obesity indicators in European participants of the EPIC-PANACEA study. *Int J Obes* 2009.

14. Kallings LV, Sierra Johnson J, Fisher RM, et al. Beneficial effects of individualized physical activity on prescription on body composition and cardiometabolic risk factors: results from a randomized controlled trial. *Eur J Cardiovasc Prev Rehabil* 2009;16(1):80-84.

15. Sundquist J, Malmstrom M, Johansson SE. Cardiovascular risk factors and the neighbourhood environment: a multilevel analysis. *Int J Epidemiol* 1999;28(5):841-845.

16. Ross CE, Mirowsky J. Neighborhood disadvantage, disorder, and health. *J Health Soc Behav* 2001;42(3):258-276.

17. Fisher KJ, Li F, Michael Y, et al. Neighborhood-level influences on physical activity among older adults: a multilevel analysis. *J Aging Phys Act* 2004;12(1):45-63.

18. Kavanagh AM, Goller JL, King T, et al. Urban area disadvantage and physical activity: a multilevel study in Melbourne, Australia. *J Epidemiol Community Health* 2005;59(11):934-940.

19. van Lenthe FJ, Brug J, Mackenbach JP. Neighbourhood inequalities in physical inactivity: the role of neighbourhood attractiveness, proximity to local facilities and safety in the Netherlands. *Soc Sci Med* 2005;60(4):763-775.

20. Piro FN, Noss O, Claussen B. Physical activity among elderly people in a city population: the influence of neighbourhood level violence and self perceived safety. *J Epidemiol Community Health* 2006;60(7):626-632.

21. Lee RE, Cubbin C, Winkleby M. Contribution of neighbourhood socioeconomic status and physical activity resources to physical activity among women. *J Epidemiol Community Health* 2007;61(10):882-890.

22. Kamphuis CB, Giskes K, Kavanagh AM, et al. Area variation in recreational cycling in Melbourne: a compositional or contextual effect? *J Epidemiol Community Health* 2008;62(10):890-898.

23. Humpel N, Owen N, Leslie E. Environmental factors associated with adults' participation in physical activity: a review. *Am J Prev Med* 2002;22:188-99.

24. McCormack G, Giles-Corti B, Lange A, et al. An update of recent evidence of the relationship between objective and self-report measures of the physical environment and physical activity behaviours. *J Sci Med Sport* 2004;7(1):Suppl 81-92.

25. Owen N, Humpel N, Leslie E et al Understanding environmental influences on walking; Review and research agenda. *Am J Prev Med* 2004;27:67-76.

26. Saelens BE, Handy SL. Built environment correlates of walking: a review. *Med Sci Sports Exerc* 2008;40(7):Suppl S550-66.

27. Wendel-Vos W, Droomers M, Kremers S, et al. Potential environmental determinants of physical activity in adults: a systematic review. *Obesity Reviews* 2007;8(5):425-40.

28. Haskell WL, Lee IM, Pate RR, et al. Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Circulation* 2007;116(9):1081-1093.

29. Merlo J, Chaix B, Ohlsson H, et al. A brief tutorial of multilevel analysis in social epidemiology: using measures of clustering in multilevel logistic regression to investigate contextual phenomena. *J Epidemiol Community Health* 2006;60:290-297.

30. Merlo J, Chaix B, Yang M et al. A brief conceptual tutorial on multilevel analysis in social epidemiology: interpreting neighborhood characteristics on individual health. *J Epidemiol Community Health* 2005;59:1022-1029.

31. Merlo J, Chaix B, Yang M, et al. A brief conceptual tutorial of multilevel analysis in social epidemiology: linking the statistical concept of clustering to the idea of contextual phenomenon. *J Epidemiol Community Health* 2005;59:443-449.

32. Burton NW, Haynes M, Wilson LA, et al. HABITAT: A longitudinal multilevel study of physical activity change in mid-aged adults. *BMC Public Health* 2009;9(1):76.

33. Burton NW, Oldenburg B, Sallis JF, et al. Measuring psychological, social, and environmental influences on leisure-time physical activity among adults. *Aust N Z J Public Health* 2007;31(1):36-43.

34. Burton NW, Turrell G, Oldenburg B, et al. The relative contribution of psychological, social, and environmental variables to physical activity. *Journal of Physical Activity and Health* 2005;2:181-96.

35. Dillman DA. *Mail and Internet Surveys: the Tailored Design Method* Chichester: Wiley; 2000.

36. Australian Bureau of Statistics. *Socio-economic Indexes for Areas, Australia, 2001.* Canberra: 2003.

37. Australian Institute of Health and Welfare. *The Active Australia Survey: a guide and manual for implementation, analysis and reporting.* Canberra: Australian Institute of Health and Welfare; 2003.

38. Timperio A, Salmon J, Rosenberg M, et al. Do logbooks influence recall of physical activity in validation studies? *Med Sci Sports Exerc* 2004;36(7):1181-1186.

39. Brown WJ, Trost SG, Bauman A, et al. Test-retest reliability of four physical activity measures used in population surveys. *J Sci Med Sport* 2004;7(2):205-215.

40. Brown W, Bauman A, Chey T, et al. Comparison of surveys used to measure physical activity. *Aust N Z J Public Health* 2004;28(2):128-134.

41. Subramanian SV, Glymour MM, Kawachi I. *Identifying Causal Ecologic Effects on Health: A Methodological Assessment.* In: S. Galea, Ed. *Macrosocial Determinants of Population Health*. New York: Springer; 2007: 301-331.

42. O'Connell AA. *Logistic Regression Models for Ordinal Response Variables*. Thousand Oaks: Sage; 2006.

43. Browne WJ. *MCMC estimation in MLwiN, Version 2.10*. Bristol: Centre for Multilevel Modelling; 2009.

44. Larsen K, Petersen JH, Budtz-Jorgensen E, et al. Interpreting parameters in the logistic regression model with random effects. *Biometrics* 2000;56:909-914.

45. Larsen K, Merlo J. Appropriate assessment of neighborhood effects on individual health: integrating random and fixed effects in multilevel logistic regression. *Am J Epidemiol* 2005;161:81-88.

46. Giles-Corti B, Donovan RJ. Socioeconomic status differences in recreational physical activity levels and real and perceived access to a supportive physical environment. *Prev Med* 2002;35(6):601-611.

47. Cerin E, Leslie E. How socio-economic status contributes to participation in leisure-time physical activity. *Soc Sci Med* 2008;66(12):2596-2609.

48. Miles R, Panton LB, Jang M, et al. Residential context, walking and obesity: two African-American neighborhoods compared. *Health Place* 2008;14(2):275-286.

49. Boyle MH, Wilms JD. Place effects for areas defined by administrative boundaries. *Am J Epidemiol* 1999;149:577-585.

50. Black J, Macinko J. Neighborhoods and obesity. *Nutrition Reviews* 2008;66(1):2-20.

51. Giles-Corti B. People or places: what should be the target? *J Sci Med Sport* 2006;9(5):357-366.

52. Macintyre S, Maciver S, Sooman A. Area, class and health: should we be focusing on places or people? *J Soc Policy* 1993;22(2):213-234.

53. Sallis JF, Cervero RB, Ascher W, et al. An ecological approach to creating active living communities. *Annu Rev Public Health* 2006;27:297-322.

54. Cochrane T, Davey RC. Increasing uptake of physical activity: a social ecological approach. *J R Soc Health* 2008;128(1):31-40.

55. Giles-Corti B, Timperio A, Bull F, et al. Understanding physical activity environmental correlates: increased specificity for ecological models. *Exerc Sport Sci Rev* 2005;33(4):175-181.

56. Sallis JF, Glanz K. The role of built environments in physical activity, eating, and obesity in childhood. *Future Child* 2006;16(1):175-181.

57. Schilling JM, Giles-Corti B, Sallis JF. Connecting active living research and public policy: transdisciplinary research and policy interventions to increase physical activity. *J Public Health Pol* 2009;30:S1-S15.

Table 1. Socioeconomic Profile (2006) of the Sampled Census Collectors Districts (n=200) Grouped by Quintile of Neighborhood Disadvantage*

	% Early school leavers†		% unskilled & semiskilled workers		% Low income families‡	
Quintiles	Mean (sd)	Min-Max	Mean (sd)	Min-Max	Mean (sd)	Min-Max
Q1 (most disadvantaged)	45.4 (11.0)	18.5-62.1	24.1 (10.9)	10.0-52.9	24.2 (9.0)	6.6-45.3
Q2	39.5 (10.0)	12.8-58.5	14.9 (5.2)	6.3-27.1	18.0 (5.4)	8.5-28.3
Q3	38.6 (9.4)	10.6-51.1	13.3 (4.6)	0.0-24.5	13.8 (4.8)	5.4-26.8
Q4	33.0 (9.1)	13.5-51.6	9.4 (2.7)	3.5-16.1	10.7 (4.5)	3.4-25.0
Q5 (least disadvantaged)	27.1 (7.3)	12.9-49.8	6.4 (3.0)	1.3-16.3	9.0 (4.4)	0.0-20.3

* Each quintile contains 40 Census Collectors Districts
†People who left school before completing grade 12 (senior secondary)
‡Families receiving $26,000 per annum or less as at the 2006 Australian census

Table 2. Socio-demographic Characteristics of the HABITAT Sample and the Brisbane Population Aged 40-65 Years as at the 2006 Census

	HABITAT (n=11,037)		Brisbane population in 2006	
	n	**%**	**N**	**%**
Neighborhood disadvantage (quintiles)				
Q1 (Most disadvantaged) *	1636	14.8	49360	17.3
Q2	1814	16.4	52777	18.5
Q3	2303	20.9	56461	19.8
Q4	2671	24.2	59121	20.8
Q5 (Least disadvantaged)	2613	23.7	67016	23.5
Sex				
Males	4867	44.1	139473	49.0
Females	6170	55.9	145262	51.0
Age				
40 – 44	2240	20.3	66396	23.3
45 – 49	2430	22.0	62930	22.1
50 - 54	2274	20.6	57232	20.1
55 - 59	2097	19.0	52762	18.5
60 - 65	1996	18.1	45308	15.9
Highest attained education level				
Bachelor's degree or higher	3458	31.3	72684	25.5
Diploma/Associate diploma	1269	11.5	27346	9.6
Certificate (trade/business)	1952	17.7	43983	15.4
School	4311	39.1	140722	49.4
Missing	47	0.4	0	0.0
Occupation				
Managers & Professionals	3669	33.2	86804	30.5
White collar	2413	21.9	48100	16.9
Blue Collar	1554	14.1	64643	22.7
Not in the labour force	2491	22.6	81934	28.8
Missing	910	8.2	3254	1.1
Household income				
$130,000 pa or more	1889	17.1	27854	18.0
$72,800 - $129,999	2845	25.8	38370	24.8
$52,000 - $72,799	1625	14.7	24140	15.6
$41,600 - $51,999	813	7.4	10354	6.7
$26,000 - $41,599	1189	10.8	19846	12.8
$0 - $25,999	1045	9.5	16148	10.4
Missing	1631	14.8	17923	11.6
Current living arrangement †				
Single and living alone	1611	14.6	--	--
Single parent	957	8.7	--	--
Single and living with friends or relatives	708	6.4	--	--
Couple (married or de facto), no children	2938	26.6	--	--
Couple (married or de facto), with children	4679	42.4	--	--
Missing	144	1.3	--	--

* Q1 contains the 40 most disadvantaged neighborhoods in the HABITAT sample and Q5 the 40 least disadvantaged

† Categories not comparable with those used in the 2006 census

Table 3. Descriptive Characteristics of the Physical Activity Variables Used in the Analysis

	n	%	Cumulative %
Active Australia Survey Questions (n=10,494)			
Total physical activity (MET.minutes/ week)			
Negligible (<90)	1526	14.5	14.5
Very Low (≥ 90 < 270)	1270	12.1	26.6
Low (≥ 270 <450)	1059	10.1	36.7
Moderate (≥ 450 <900) *	1788	17.0	53.8
High (≥ 900 <1800)	2216	21.1	74.9
Very high (≥ 1800)	2635	25.1	100.0
General walking (minutes last week)			
Negligible (<30)	2420	23.1	23.1
Very low (≥ 30 < 90)	2353	22.4	45.5
Low (≥ 90 <150)	1954	18.6	64.1
Moderate (≥ 150 <300)	2223	21.2	85.3
High (≥ 300)	1544	14.7	100.0
Moderate physical activity (minutes last week)			
Negligible (<30)	7672	73.1	73.1
Very low (≥ 30 < 90)	874	8.3	81.4
Low (≥ 90 <150)	623	5.9	87.4
Moderate (≥ 150 <300)	671	6.4	93.2
High (≥ 300)	654	6.2	100.0
Vigorous physical activity (minutes last week)			
Low (<60)	6273	59.8	59.8
Moderate (≥ 60 < 120)	1169	11.1	70.9
High (≥ 120 <240)	1635	15.6	86.5
Very high (≥ 240)	1417	13.5	100.0
Walking for transport (minutes last week) (n=10, 745)			
None	6985	65.0	65.0
Low (≥ 1 < 60)	1474	13.7	78.7
Moderate (≥ 60 <150)	1578	14.7	93.4
High (≥ 150)	708	6.6	100.0
Cycling for transport (minutes last week)(n=10,702)			
None	9944	96.2	--
Some	396	3.8	--

* Physical activity at recommended levels or above (37)

Table 4. Estimates of Between-Neighborhood Variation in Logit Physical Activity – Posterior Mean and Standard Error of Variance Parameter Obtained Using MCMC Simulation

	Posterior mean (se) of between-neighborhood variance			% difference in variance	
	Model 1*	Model 2†	Model 3‡	Model 1 – Model 2	Model 2 – Model 3
Total physical activity (MET.minutes/ week)					
Negligible (<90) (Reference group)					
Very Low (≥ 90 < 270)	0.161 (0.038)	0.145 (0.036)	0.148 (0.037)	-9.9	+2.1
Low (≥ 270 <450)	0.166 (0.040)	0.145 (0.036)	0.140 (0.036)	-12.7	-3.4
Moderate (≥ 450 <900)	0.192 (0.041)	0.134 (0.032)	0.134 (0.032)	-30.2	0.0
High (≥ 900 <1800)	0.232 (0.046)	0.135 (0.031)	0.121 (0.029)	-41.8	-10.4
Very high (≥ 1800)	0.317 (0.057)	0.189 (0.042)	0.155 (0.036)	-40.4	-18.0
General walking (minutes last week)					
Negligible (<30) (Reference group)					
Very low (≥ 30 < 90)	0.142 (0.031)	0.118 (0.027)	0.121 (0.027)	-16.9	+2.5
Low (≥ 90 <150)	0.173 (0.037)	0.143 (0.032)	0.142 (0.032)	-17.3	-0.7
Moderate (≥ 150 <300)	0.181 (0.038)	0.142 (0.031)	0.138 (0.031)	-21.5	-2.8
High (≥ 300)	0.237 (0.051)	0.191 (0.044)	0.190 (0.044)	-19.4	-0.5
Moderate physical activity (minutes last week)					
Negligible (<30) (Reference group)					
Very low (≥ 30 < 90)	0.120 (0.031)	0.102 (0.027)	0.099 (0.026)	-15.0	-2.9
Low (≥ 90 <150)	0.134 (0.036)	0.107 (0.029)	0.100 (0.027)	-20.1	-6.5
Moderate (≥ 150 <300)	0.140 (0.037)	0.130 (0.036)	0.125 (0.036)	-7.1	-3.8
High (≥ 300)	0.120 (0.033)	0.114 (0.032)	0.110 (0.031)	-5.0	-3.5
Vigorous physical activity (minutes last week)					
Low (<60) (Reference group)					
Moderate (≥ 60 < 120)	0.115 (0.026)	0.073 (0.018)	0.064 (0.016)	-36.5	-12.3
High (≥ 120 <240)	0.146 (0.029)	0.080 (0.019)	0.067 (0.016)	-45.2	-16.3
Very high (≥ 240)	0.188 (0.037)	0.108 (0.027)	0.082 (0.021)	-42.5	-24.1
Walking for transport (minutes last week)					
None (Reference group)					
Low (≥ 1 < 60)	0.226 (0.039)	0.197 (0.036)	0.196 (0.037)	-12.8	-0.5
Moderate (≥ 60 <150)	0.314 (0.049)	0.289 (0.047)	0.273 (0.046)	-8.0	-5.5
High (≥ 150)	0.499 (0.085)	0.414 (0.077)	0.401 (0.078)	-17.0	-3.1
Cycling for transport (minutes last week)					
None (Reference group)					
Some	0.473 (0.111)	0.371 (0.104)	0.361 (0.103)	-21.6	-2.7

* Model 1: Between neighborhood variation in physical activity unconditioned on any other factor
† Model 2: Model 1 plus adjustment for within-neighborhood variation in age, sex, household-type, education, occupation, and household income
‡ Model 3: Model 2 plus adjustment for neighborhood socioeconomic disadvantage

Table 5. Interval odds ratios (80%) for the influence of neighborhood disadvantage on between-neighborhood variance in physical activity participation*†‡

	Q1 v Q2	Q1 v Q3	Q1 v Q4	Q1 v Q5
Total physical activity (MET.minutes/ week)				
Negligible (<90) (Reference group)				
Very Low (≥ 90 < 270)	0.63, 1.68	0.69, 1.85	0.70, 1.89	0.78, 2.08
Low (≥ 270 <450)	0.93, 2.41	0.79, 2.07	0.97, 2.53	0.88, 2.29
Moderate (≥ 450 <900)	0.67, 1.71	0.74, 1.89	0.81, 2.07	0.82, 2.10
High (≥ 900 <1800)	0.84, 2.04	0.83, 2.02	0.95, 2.33	1.14, 2.78
Very high (≥ 1800)	0.71, 1.96	0.67, 1.84	0.91, 2.50	1.23, 3.37
General walking (minutes last week)				
Negligible (<30) (Reference group)				
Very low (≥ 30 < 90)	0.66, 1.60	0.72, 1.76	0.65, 1.59	0.80, 1.96
Low (≥ 90 <150)	0.76, 1.99	0.68, 1.79	0.75, 1.97	0.83, 2.17
Moderate (≥ 150 <300)	0.72, 1.87	0.65, 1.68	0.69, 1.78	0.86, 2.23
High (≥ 300)	0.62, 1.89	0.63, 1.92	0.65, 2.00	0.86, 2.63
Moderate physical activity (minutes last week)				
Negligible (<30) (Reference group)				
Very low (≥ 30 < 90)	0.85, 1.90	0.96, 2.15	0.94, 2.11	1.01, 2.27
Low (≥ 90 <150)	0.75, 1.70	0.99, 2.23	0.81, 1.82	1.08, 2.43
Moderate (≥ 150 <300)	0.59, 1.47	0.64, 1.59	0.58, 1.43	0.85, 2.10
High (≥ 300)	0.80, 1.87	0.90, 2.10	0.93, 2.18	1.12, 2.62
Vigorous physical activity (minutes last week)				
Low (<60) (Reference group)				
Moderate (≥ 60 < 120)	0.94, 1.80	0.84, 1.60	1.03, 1.97	1.12, 2.15
High (≥ 120 <240)	0.76, 1.48	0.77, 1.50	0.95, 1.84	1.09, 212
Very high (≥ 240)	0.75, 1.56	0.72, 1.51	1.00, 2.08	1.22, 2.53
Walking for transport (minutes last week)				
None (Reference group)				
Low (≥ 1 < 60)	0.53, 1.65	0.47, 1.47	0.46, 1.43	0.45, 1.41
Moderate (≥ 60 <150)	0.53, 2.01	0.45, 1.73	0.37, 1.43	0.37, 1.40
High (≥ 150)	0.37, 1.89	0.30, 1.52	0.30, 1.51	0.29, 1.47
Cycling for transport (minutes last week)				
None (Reference group)				
Some	0.37, 1.72	0.33, 1.56	0.32, 1.48	0.45, 2.11

* Q1 contains the 40 most disadvantaged neighborhoods in the HABITAT sample and Q5 the 40 least disadvantaged neighborhoods

† All models adjusted for within-neighborhood variation in age, sex, household-type, education, occupation, and household income

‡ Estimates derived from Model 3 in Table 4

Table 6. Neighborhood Socioeconomic Disadvantage and Total MET.minutes of Physical Activity, Walking, Moderate, and Vigorous Activity, and Walking and Cycling for Transport * †

	Q1 (most disadvantaged)	Q2		Q3		Q4		Q5 (least disadvantaged)	
Total physical activity (MET.minutes/ week)	OR	OR	CrI	OR	CrI	OR	CrI	OR	CrI
Negligible (<90) (Reference group)									
Very Low (≥ 90 < 270)	1.00	1.03	0.75, 1.41	1.13	0.84, 1.53	1.15	0.85, 1.56	1.27	0.92, 1.75
Low (≥ 270 <450)	1.00	1.49	1.08, 2.08	1.28	0.94, 1.76	1.57	1.14, 2.15	1.42	1.01, 1.99
Moderate (≥ 450 <900)	1.00	1.07	0.80, 1.44	1.18	0.89, 1.56	1.29	0.97, 1.72	1.32	0.98, 1.77
High (≥ 900 <1800)	1.00	1.31	0.98, 1.74	1.29	0.99, 1.70	1.49	1.13, 1.96	1.78	1.34, 2.38
Very high (≥ 1800)	1.00	1.18	0.88, 1.59	1.11	0.84, 1.47	1.51	1.14, 2.01	2.03	1.52, 2.74
General walking (minutes last week)									
Negligible (<30) (Reference group)									
Very low (≥ 30 < 90)	1.00	1.02	0.79, 1.32	1.23	0.94, 1.62	1.16	0.89, 1.53	1.08	0.80, 1.47
Low (≥ 90 <150)	1.00	1.13	0.88, 1.45	1.11	0.85, 1.45	1.04	0.80, 1.37	1.10	0.82, 1.47
Moderate (≥ 150 <300)	1.00	1.02	0.80, 1.31	1.22	0.94, 1.58	1.11	0.85, 1.44	1.14	0.86, 1.54
High (≥ 300)	1.00	1.25	0.97, 1.63	1.34	1.02, 1.75	1.39	1.06, 1.82	1.50	1.12, 2.04
Moderate physical activity (minutes last week)									
Negligible (<30) (Reference group)									
Very low (≥ 30 < 90)	1.00	1.27	0.92, 1.75	1.13	0.79, 1.63	0.93	0.66, 1.31	1.23	0.87, 1.73
Low (≥ 90 <150)	1.00	1.44	1.06, 1.96	1.49	1.06, 2.09	1.01	0.73, 1.40	1.37	0.98, 1.91
Moderate (≥ 150 <300)	1.00	1.41	1.04, 1.92	1.21	0.86, 1.71	0.91	0.66, 1.26	1.42	1.02, 1.98
High (≥ 300)	1.00	1.52	1.11, 2.07	1.62	1.15, 2.27	1.34	0.97, 1.85	1.72	1.23, 2.40
Vigorous physical activity (minutes last week)									
Low (<60) (Reference group)									
Moderate (≥ 60 < 120)	1.00	1.30	1.00, 1.71	1.16	0.89, 1.50	1.42	1.10, 1.83	1.55	1.20, 2.02
High (≥ 120 <240)	1.00	1.06	0.83, 1.35	1.07	0.85, 1.36	1.32	1.05, 1.66	1.52	1.21, 1.93
Very high (≥ 240)	1.00	1.08	0.83, 1.41	1.04	0.80, 1.35	1.44	1.12, 1.86	1.75	1.36, 2.27

Walking for transport (minutes last week)									
None (Reference group)									
Low (≥ 1 < 60)	1.00	0.94	0.71, 1.25	0.83	0.63, 1.10	0.81	0.62, 1.07	0.80	0.60, 1.07
Moderate (≥ 60 <150)	1.00	1.03	0.76, 1.39	0.88	0.65, 1.19	0.73	0.54, 0.99	0.72	0.53, 0.98
High (≥ 150)	1.00	0.84	0.57, 1.24	0.68	0.46, 1.00	0.67	0.45, 0.98	0.65	0.44, 0.97
Cycling for transport (minutes last week)									
None (Reference group)									
Some	1.00	0.79	0.49, 1.27	0.72	0.46, 1.15	0.68	0.44, 1.08	0.97	0.62, 1.54

* Q1 contains the 40 most disadvantaged neighborhoods in the HABITAT sample and Q5 the 40 least disadvantaged

† All models adjusted for within-neighborhood variation in age, sex, household-type, education, occupation, and household income