Author(s): Ge Yu, Adrian Renton, Elena Schmidt, Patrick Tobi, Marcello Bertotti, Paul Watts and Shahana Lais
Title: A multilevel analysis of the association between social networks and support on leisure time physical activity: evidence from 40 disadvantaged areas in London
Year of publication: 2011
Citation: Yu, G., Renton, A., Schmidt, E., Tobi, P., Bertotti, M., Watts, P. and Lais, S. (2011), 'A multilevel analysis of the association between social networks and support on leisure time physical activity: evidence from 40 disadvantaged areas in London', *Health and Place*, 17(5), pp. 1023-1029, DOI: 10.1016/j.healthplace.2011.07.002.

Link to published version:
http://dx.doi.org/10.1016/j.healthplace.2011.07.002

Abstract:

There has been extensive conceptual and empirical work on the associations between social relations and health in recent years. However, the specific pathways through which social interactions impact on health have not been fully elucidated. The aim of this paper is to estimate associations between leisure time physical activity (LTPA) and social networks and support. Using data from a cross-sectional household survey in 40 disadvantaged Lower Super Output Areas in London, we applied a multilevel model to investigate psychosocial and environmental determinants of physical activity in these populations. Our findings present a strong case for the influence of individual-level social networks on the level of LTPA, although the associations between the types of social support and LTPA were insignificant. We also found that crime rate was an important area-level correlates of LTPA.

Introduction

Physical activity (PA) has a strong effect on reducing risk of premature death and several chronic diseases (Warburton et al., 2006). However, only 34% of the adult population in England achieve the minimum levels of PA recommended by the Chief Medical Officer (NHS, 2010). Understanding the factors that influence PA is therefore a major priority for public health researchers and practitioners in order to inform the development of effective policies and interventions to drive these low levels of PA upwards (Haskell et al., 2009).

There is a growing body of evidence to suggest that both socio-economic circumstances and environments may act as barriers or facilitators in individual and community participation in PA (Ali and Lindstrom, 2006; Lindstrom et al., 2001; Lindstrom et al., 2003). Examples include personal income, social networks, social support, and crime rates (Booth et al., 2000; Giles-Corti and Donovan, 2002; Greiner et al., 2004; Leyden, 2003).

Social capital is an important indicator of individual and community social environment. The measure has been firmly established in the political lexicon in the UK and has generated a lot of interest within government research, statistics and policy making. Its importance has been strongly emphasised in the recently published strategic review of health inequalities in England (Marmot, 2010).

Social capital emphasises the role of groups or networks (Kawachi et al., 2004; Putnam, 2000; Szreter and Woolcock, 2004), and is often viewed as the capacity of individuals to command scarce resources by virtue of their personal memberships in these networks or broader social structures (Portes, 1998). In this context, social networks and support refers to the social embeddedness of individuals (Lindstrom et al., 2004; Lochner et al., 1999), and are central to the notion of social capital.

Researchers investigating the relationship between social environments and health-related behaviour have mostly concluded that health outcomes and behaviours are socially patterned, negatively impacting those that live in resource-deficient social contexts (Berkman and Kawachi, 2000). Those who examined the role of social capital in health suggested that social networks may influence health in several ways, including the diffusion of knowledge about healthy behaviours and lifestyles, and the maintenance of healthy behavioural norms through informal social control (Berkman, 1985; Cassel, 1976). Some researchers, however, argued that social networks may also be important in diffusion of risk factors for ill health such as smoking and obesity (Christakis and Fowler, 2007).

This study has a particular focus on social networks and support and the association between these variables and self-reported levels of physical activity. Several studies have looked at the impact of social support on PA. Allen et al. (2001), for example, analysed data from the Coronary Artery Risk Development in Young Adults (CARDIA) study and found that social support was positively associated with increased PA in all groups except black women. A recent systematic review (Wendel-Vos et al., 2007) of 47 observational studies concluded that experiencing higher levels of social support and having a companion with whom to engage in PA are the factors most consistently associated with higher levels of PA.

Although the influence of social capital factors on health behaviour is now widely recognized, few published PA studies, particularly in Europe, have empirically investigated the individual impact of social networks and support on health and behaviour (Emmons, 2000; Lindstrom et al., 2003). In addition, previous studies have been limited by the use of area-level measures that are simply aggregates of individual responses. However, Portes and Landolt (1996) argued that collective social capital factors cannot simply be the sum of individual-level variables. The effects of social capital at the contextual level may be confounded with the effects of social networks and support at the individual level. Aggregated data without taking into account individual compositional differences can lead to spurious conclusions about whether social capital collectively benefits members of a community over and above the individual benefits of social networks and support. Baron *et al.* (2001) further suggested that social capital is aggregated up across different levels and that the validity of social capital depends on its contextualisation. As a result, Duncan et al. (1998) argued multilevel modelling is a more appropriate analytical approach to study individual and collective effects of social capital factors. However, only few multilevel studies have tried to separate the individual and contextual effects of social capital on health.

The aim of this study is to utilise the multilevel methodology to empirically investigate the importance of social networks and support for people's personal health behaviour, particularly leisure time physical activity (LTPA). Social networks are measured through the interactions with relatives, friends, and neighbours; while social support was assessed through individual reliance on care, financial help and information in the time of hardship (Cohen et al., 2000). The study was conducted in 40 disadvantaged areas in London. The key distinction of this paper is that social networks and support were measured at individual level rather than the aggregated measures used by others. We believe that individual level data are more appropriate to capture the richness of social interactions and explain variations in LTPA. The effect analysis has been adjusted for the socio-demographic and socio-economic characteristics of individuals and socio-economic features of the areas where they live.

Methods

Study design

A cross-sectional household survey was conducted among adults (16 years or over) living at randomly selected addresses in 40 deprived (based on the Index of Multiple Deprivation) Lower Super Output Areas (LSOAs) in London. The survey used face-to-face questionnaire-based interviews and examined health and wellbeing with a focus on diet, LTPA, use of healthcare services and mental health and wellbeing.

Study Sample

Addresses in each target area were selected from the Post Office Address File using simple probability sampling. The total mid-2008 estimated population (16+) of the 40 areas was 53,138 people (ONS). All eligible adults residing at the selected addresses were invited to take part and a total sample of 4107 residents was achieved. The average number of persons in each household was 1.65 across 40 areas. The household response rate, which is defined as the proportion of productive addresses out of the number of eligible addresses, was 73%

over all neighbourhoods, with a maximum of 89% in Evelyn and a minimum of 41% in South Acton. At the individual level the adjusted response rate defined as the number of completed interviews divided by the number of eligible cases, was 65% overall, ranging from 33% in South Acton to 76% in Evelyn.

Measures of physical activity

To measure LTPA we used the short version of the International Physical Activity Questionnaire (IPAQ) (Craig CL, 2003), which assesses self-reported LTPA within the past 7 days. The validity and reliability[1] of the IPAQ has been tested in multiple settings (Rutten and Abu-Omar, 2004) and it has been shown to be suitable for use in large-scale multi-site surveys (Craig et al., 2003).

The questionnaire asks respondents to report the number of days per week and the number of minutes per day spent in vigorous, moderate, and walking activity during leisure time over a seven-day period. This allows calculation of the number of hours spent in moderate and/or vigorous activity per week, which is then transferred to energy expenditure estimates known as Metabolic Equivalent Task (MET). MET is measured in MET-hours or MET-minutes per week and is calculated by multiplying the number of hours dedicated to each activity class by the specific MET score recommended for that activity (Ainsworth et al., 1993; Ainsworth et al., 2000). The Chief Medical Officer recommends a target of at least 690 MET-minutes (11.5 MET-hours) from moderate or vigorous activity per week (Department of Health, 2004). The MET-minutes data in this study were heavily skewed to the right and the overall variance was much larger than the mean; hence a negative binomial model was fit to the data with MET-minutes modelled as a continuous outcome for each respondent.

Measures of social networks and support

Social networks and support were assessed through frequency of contacts within the participants' networks of relatives, friends and neighbours, and the quality of such contacts measured through opportunities for care, financial support and information the individuals could receive at the time of hardship (see Table 1). The questions were drawn from the Office of National Statistics (ONS) Social Capital Question Bank. They were designed to identify the size of the individuals' networks and the quality of interactions, as a stress-buffering mechanism (Cohen et al., 2000). ONS has run a factor analysis and finds that these questions have high correlations with social networks and support (Babb, 2005). The same measures have been used in a number of national surveys including the General Household Survey, Citizenship Survey and the Survey of English Housing. The responses to social network were constructed into an additive scale as a continuous overall index ranging from 0 to 28. The responses to three aspects of social support were categorized into none, one or two, and more than two (Table 1).

[Insert Table 1]

[1] Spearman's ρ for the short form is 0.76

Individual-level factors

At the individual level, we controlled for three sociodemographic (age, gender, and marital status) and three socioeconomic (education attainment, job status, and personal income) characteristics (Table 2). These characteristics were selected as they have previously been shown to predict levels of PA (National Center for Health Statistics, 2009).

Age was categorized into six groups: 16-24, 25-34, 35-44, 45-54, 55-64, and 65 and older. Marital status compared never married with currently married/in partnership and formerly married. Education attainment compared higher education with primary, secondary, and A-level. Respondents' economic activity was stratified into employed, unpaid housework, full-time student, unemployed, retired, disable and others. Monthly individual income compared £400-1249 with £0-399 and more than £1250. In addition, we adjusted for two binary variables describing how safe respondents feel generally in their neighbourhood during the daytime and after dark.

Community-level factors

We also explored the impact of living in a socially deprived area on LTPA, measured by a constructed IMD score used by the UK government to indicate the impact of material deprivation at the community level. A higher value on the IMD index corresponds to a more deprived community. Three continuous indicators were utilized to construct area-level factors in this study: (1) IMD score, (2) IMD crime score, and (3) combined living environment indicator. The IMD crime score, released by the Office of the Deputy Prime Minister, is an index of crime at a small area level. It is based on the levels of recorded crime for four major crime themes, presenting the occurrence of personal and material victimisation at a small area level. A high score indicates a possible area of high crime and a low score indicates a possible area of low crime. As well, it is used as an index of social cohesion (Walberg et al., 1998).

Data analysis

The data were analysed using STATA SE v11.1 (StataCorp, Texas USA). No extreme or implausible data were identified and all cases were included in subsequent analysis.

Given the hierarchical structure of the sample and the continuous outcome, we adopted a negative binomial multilevel modelling approach that allows for extra-Poisson variation, in conjunction with the Huber-White sandwich estimator of variance. It makes it possible to simultaneously examine the individual and contextual factors influencing health behaviour.

Fifteen covariates included in the regression models had some missing data, the likely values of which were estimated by conditioning on the non-missing categories (1314 out of 4107). This treatment of missing values requires no additional assumptions on their distribution. The sampling weight is calculated as the inverse of selection probability based on mid-2008 population estimate (16+) from the ONS.

The analysis was done in two steps. Firstly we assumed the mechanism of missing-data in our study is missing at random (MAR). In other words, the probability of an observation being missing may depend on observed values but not on unobserved values. Under this assumption, we ran two models:

- Model 1 is a multivariate model in which only individual-level factors were included;

- Model 2 is a multilevel model which predicted an aspect of behaviour in terms of a combination of individual and area circumstances and the interactions between them.

The results of random effects were presented as the estimated residual intraclass correlation (rho) of the latent response to justify applying a multilevel model to our analysis. Multilevel statistical models allow for the estimation of contextual effects of area-level factors by accounting for the spatial clustering of individuals within communities (Subramanian et al., 2003). Two level negative binomial models with random intercepts were estimated using STATA software (version SE11.1). Incidence rate ratios were estimated from summary odds ratios or regressions coefficient. The respondents were nested within 40 London areas.

The percentage of missing values across the 15 variables of interest including the dependent variables ranged from 1.1% to 50.7%. The complete-case method, which was applied in the first step, might make the usually unrealistic assumption that the data are missing completely at random (MCAR) or at least MAR. To deal with these missing data, we applied multiple imputation (MI), which was conceived by Robin (1987) and described further by Little and Rubin (2002) and Schafer (1997). MI imputes each missing value multiple times. Inferences using the multiply imputed data thus account for the missing data and the uncertainty in the imputations. Although some researchers avoid imputation approaches because of the fear of "making up data", complete-case analyses in fact require stronger assumptions than imputation. In the second step, we created a set of "complete" data sets with no missing data and re-ran our models. We found that the model derived after complete case analysis did not show striking difference from the model obtained after using multiple imputation of missing data. For instance, the regression coefficients for friend networks score, neighbour networks score, and community-level crime score are 1.03, 1.07, and 0.60 respectively for the complete case analysis, and 1.02, 1.06, and 0.70 for the MI analysis. This is mostly likely because most of our variables revealed a relatively limited number of missing values except for personal income (Table 2). Based on simulation studies and theoretical reasoning, it is widely advocated that imputation of missing data is better than ignoring missing data (Greenland and Finkle, 1995; Little, 1992; Rubin and Schenker, 1991; Toutenburg, 1990). Hence, incidence rate ratios (IRRs)[2] were estimated from summary odds ratios or regressions in the final model based on MI, and 95% confidence level (CIs) were calculated for each estimate.

Results

Table 2 lists the individual- and area-level descriptive statistics. Given the non-normal distribution of energy expenditure in many populations, we present the continuous outcome as median MET-minutes/week rather than mean MET-minutes/week. Respondents were fairly evenly distributed across the age groups and personal income. Almost half (45%) of respondents were never married and 13% were formerly married. About 44% were employed.

[Insert Table 2]

[2] Incidence rate ratios are interpreted similar to relative risk and odds ratios. A value above one indicates a positive effect whereas a value below one indicates a negative effect.

Table 2 also presents univariable associations between MET-minutes and each individual-level explanatory variable.

The overall variance was 6515086 and the mean was 2107, hence a Poisson model was not considered appropriate since it assumes the mean and the variance to be approximately the same. A negative binomial model was fit to the data. Table 3 presents results (IRRs) from the two models we applied. After adjustment for individual sociodemographic and socioeconomic characteristics, two social network indicators (friends and neighbours) achieved conventional levels of statistical significance in association with MET-minutes/week. The incident rate ratio for friend networks and neighbour networks are 1.02 and 1.06 respectively. Suggesting that a one-unit increase in friend networks score and neighbour networks score will result in 2% and 6% in MET-minutes/week. Inclusion of the area-level variables had minimal effect on the contribution of individual-level variables to the outcome. Interestingly, we did not find statistically significant evidence for the proposition that either relative networks or social support indicators change individuals' LTPA at 95% level.

According to the intra-community correlation coefficient, 8.6% of the variance of MET-minutes in Model 1 can be attributed to area-level factors. This variation remained significant, even after controlling for area-level characteristics (Model 2). As judged by proportional change in variance, 26% of the variance of MET-minutes across areas was explained by area-level factors (Model 2).

[Insert Table 3]

MET-minutes were associated with one socio-demographic and all socio-economic variables we looked at. Model 2 found that age, gender, marital status and participation in the labour market were significantly related to MET-minutes but not education or personal income. Perhaps unsurprisingly, women, older participants and those in partnerships were more likely to report lower levels of LTPA. Those who were not in employment reported significantly lower LTPA compared to those employed. There was no significant association between perception of the area safety and LTPA. However, the crime score indicator was the only area-level indicator significantly negatively associated with LTPA.

Discussion and Conclusions

The maintenance of regular physical activity is an important feature of individual lifestyles and is essential for effective health promotion (Powell and Paffenbarger, 1985). However, individually-tailored intervention programmes designed to encourage people to be more physically active have had limited long-term impact (Iverson et al., 1985; Kahn et al., 2002; Martin and Dubbert, 1982). A key reason for this may be the limited understanding of the determinants of regular physical activity habits. The purpose of this study was to therefore to empirically explore associations between individual social networks and support, local environment, and leisure time physical activity levels using a multilevel statistical framework.

Our findings showed that higher levels of individual social networks with friends and neighbours contributed to higher LTPA. This is consistent with previous research, which found close associations between friend networks and PA (VicHealth, 2007). The association between close social networks such as relatives and LTPA appears to be more complex, as these networks can exercise both positive and negative influences on PA (Putnam, 2000). We found no impact of strong relative networks on LTPA and living with a partner has in fact

had inverse effect on the levels of LTPA. The associations between social support and LTPA were also statistically insignificant at individual level. With regards to socio-economic and area level predictors, this study suggests that young age groups, male, the single, and economically active people were more likely to engage in higher levels of LTPA.

Of particular interest in this investigation was the possible contextual effect of the social environment on the incidence-rate of reporting higher levels of LTPA. Although participants in many qualitative studies (Eyler et al., 1998; Eyler et al., 2002; Henderson and Ainsworth, 2003) cited crime and safety issues as barriers to physical activity, few quantitative studies have assessed crime as a barrier to individuals' physical activity, particularly, in disadvantaged areas (King et al., 2000). Stronegger et al. (2010) found a significant association between the perception of better residential environment and higher levels of LTPA and self-reported health. This study found that crime rate at the community-level has a significantly negative effect on LTPA level, whereas the perceived safety of one's physical environment is not a personal barrier to LTPA behaviour. This finding is not surprising given the propensity for individuals to go outside of their immediate neighbourhood to exercise (McGinn et al., 2008), as well as the results that employment (which could be outside the immediate living environment) was associated with a higher level of LTPA.

Our findings provide support for policy implications to improving health and physical activity through understanding the individual in their social context. The uniqueness of our findings is that the association between LTPA and social networks shown earlier in various contexts is also demonstrated in communities experiencing high levels of deprivation. Secondly, a better understanding of the relationships between crime and physical activity may assist in the development of new approaches to promote positive health behaviours. Policing strategies based on the broken windows theory emerged during the 1990s and focus on enforcing quality of life infractions to decrease more serious crime (Kelling and Bratton, 1996; Kelling and Bratton, 1998). These actions can be also a method for increasing opportunities for physical activity that do not require any immediate changes to the physical infrastructure. Thirdly, in our study we have used six different aspects of social networks and social support, thus providing a more nuanced understanding of the association between social networks and support, and physical activity. Finally, this study has obtained more accurate results regarding the associations of interest by using multiple imputation method, which prevents a loss in power from having to exclude any observation with a missing value.

The study is not without limitations. An important weakness of cross-sectional studies is that cause and effect cannot be disentangled, and the possibility that unmeasured confounding factors explain the associations observed cannot be ruled out. We also cannot say anything about the direction of the associations we identified. While it is likely that poorer social networks may lead to lower LTPA levels, it is also plausible that lower LTPA leads to lower levels of engagement in social networks. Longitudinal research will be necessary to explore these issues.

References

Ainsworth, B.E., Haskell, W.L., Leon, A.S., Jacobs, D.R., 1993. Compendium of Physical Activities: classification of energy costs of human physical activities. Medicine and Science in Sports and Exercise 25, 71.

Ainsworth, B.E., Haskell, W.L., Whitt, M.C., Irwin, M.L., Swartz, A.M., Strath, S.J., O Brien, W.L., Bassett, D.R., Schmitz, K.H., Emplaincourt, P.O., 2000. Compendium of Physical Activities: an update of activity codes and MET intensities. Medicine and Science in Sports and Exercise 32, S498-S504.

Ali, S.M., Lindstrom, M., 2006. Psychosocial work conditions, unemployment, and leisure-time physical activity: A population-based study. Scandinavian Journal of Public Health 34, 209-216.

Allen, J., Markovitz, J., Jacobs, D.R., Jr., Knox, S.S., 2001. Social Support and Health Behavior in Hostile Black and White Men and Women in CARDIA. Psychosom Med 63, 609-618.

Babb, P., 2005. Measurement of social capital in the UK. Office for National Statistics.

Baron, S., Field, J., Schuller, T., 2001. Social Capital - Critical Perspectives. Oxford University Press.

Berkman, L., Kawachi, I., 2000. A historical framework for social epidemiology. Oxford University Press, New York.

Berkman, L.F., 1985. The relationship of social networks and social support to morbidity and mortality, Social support and health. San Diego, CA, US: Academic Press, pp. 241-262.

Booth, M.L., Owen, N., Bauman, A., Clavisi, O., Leslie, E., 2000. Social-cognitive and perceived environment influences associated with physical activity in older Australians. Preventive Medicine 31, 15-22.

Cassel, J., 1976. Contribution of Social-Environment to Host-Resistance - 4th Wade Hampton Frost Lecture. American Journal of Epidemiology 104, 107-123.

Christakis, N.A., Fowler, J.H., 2007. The spread of obesity in a large social network over 32 years. New England Journal of Medicine 357, 370-379.

Cohen, S., Underwood, L., Gottlieb, B., 2000. Measuring and intervening in social support, in: Cohen, S., Underwood, L., Gottlieb;, B. (Eds.), Social relationships and health. Oxford University Press, New York, pp. 3-25.

Craig, C., AL, M., M, S., AE, B., ML, B., BE, A., M, P., U, E., A, Y., JF, S., P, O., 2003. The International Physical Activity Questionnaire (IPAQ): A comprehensive reliability and validity study in twelve countries. Medicine and Science in Sports and Exercise, 15.

Craig CL, M.A., Sjöström M, Bauman AE, Booth ML, Ainsworth BE, Pratt M, Ekelund U, Yngve A, Sallis JF, Oja P., 2003. International physical activity questionnaire: 12-country reliability and validity. Medicine and Science in Sports and Exercise 35, 1381-1395.

Department of Health, 2004. At least five a week: Evidence on the impact of physical activity and its relationship to health. HMSO, London.

Duncan, C., Jones, K., Moon, G., 1998. Context, composition and heterogeneity: Using multilevel models in health research. Social Science & Medicine 46, 97-117.

Emmons, K.M., 2000. Health behaviors in a social context, in: Berkman, L.F., Kawachi, I. (Eds.), Social Epidemiology. Oxford University Press, New York.

Eyler, A.A., Baker, E., Cromer, L., King, A.C., Brownson, R.C., Donatelle, R.J., 1998. Physical activity and minority women: a qualitative study. Health Educ Behav 25, 640-652.

Eyler, A.A., Matson-Koffman, D., Vest, J.R., Evenson, K.R., Sanderson, B., Thompson, J.L., Wilbur, J., Wilcox, S., Young, D.R., 2002. Environmental, policy, and cultural factors related to physical activity in a diverse sample of women: The Women's Cardiovascular Health Network Project--summary and discussion. Women Health 36, 123-134.

Giles-Corti, B., Donovan, R.J., 2002. The relative influence of individual, social and physical environment determinants of physical activity. Social Science & Medicine 54, 1793-1812.

Greenland, S., Finkle, W.D., 1995. A Critical Look at Methods for Handling Missing Covariates in Epidemiologic Regression Analyses. American Journal of Epidemiology 142, 1255-1264.

Greiner, K.A., Li, C.Y., Kawachi, I., Hunt, D.C., Ahluwalia, J.S., 2004. The relationships of social participation and community ratings to health and health behaviors in areas with high and low population density. Social Science & Medicine 59, 2303-2312.

Haskell, W.L., Blair, S.N., Hill, J.O., 2009. Physical activity: health outcomes and importance for public health policy. Preventive Medicine 49, 280-282.

Henderson, K.A., Ainsworth, B.E., 2003. A synthesis of perceptions about physical activity among older African American and American Indian women. American Journal of Public Health 93, 313-317.

Iverson, D., Fielding, J., Crow, R., Christenson, G., 1985. The promotion of physical activity in the United States population: The status of program in medical, worksite, community, and school settings. Public Health Rep 100, 13.

Kahn, E.B., Ramsey, L.T., Brownson, R.C., Heath, G.W., Howze, E.H., Powell, K.E., Stone, E.J., Rajab, M.W., Corso, P., Briss, P.A., Serv, T.F.C.P., 2002. The effectiveness of interventions to increase physical activity - A systematic review. American Journal of Preventive Medicine 22, 73-108.

Kawachi, I., Kim, D., Coutts, A., Subramanian, S.V., 2004. Commentary: Reconciling the three accounts of social capital. International Journal of Epidemiology 33, 682-690; discussion 700-684.

Kelling, G., Bratton, W., 1996. Fixing Broken Windows: Restoring Order and Reducing Crime in our Communities. NY: Martin Kessler Books, New York.

Kelling, G.L., Bratton, W.J., 1998. Declining Crime Rates: Insiders' Views of the New York City Story. The Journal of Criminal Law and Criminology (1973-) 88, 1217-1232.

King, A.C., Castro, C., Wilcox, S., Eyler, A.A., Sallis, J.F., Brownson, R.C., 2000. Personal and environmental factors associated with physical inactivity among different racial-ethnic groups of U.S. middle-aged and older-aged women. Health Psychology 19, 354-364.

Leyden, K.M., 2003. Social capital and the built environment: The importance of walkable neighborhoods. American Journal of Public Health 93, 1546-1551.

Lindstrom, M., Hanson, B.S., Ostergren, P.O., 2001. Socioeconomic differences in leisure-time physical activity: the role of social participation and social capital in shaping health related behaviour. Social Science & Medicine 52, 441-451.

Lindstrom, M., Moghaddassi, M., Merlo, J., 2003. Social capital and leisure time physical activity: a population based multilevel analysis in Malmo, Sweden. Journal of Epidemiology and Community Health 57, 23-28.

Lindstrom, M., Moghaddassi, M., Merlo, J., 2004. Individual self-reported health, social participation and neighbourhood: a multilevel analysis in Malmo, Sweden. Preventive Medicine 39, 135-141.

Little, R.J.A., 1992. Regression With Missing X's: A Review. Journal of the American Statistical Association 87, 1227-1237.

Little, R.J.A., Rubin, D.B., 2002. Statistical analysis with missing data, 2nd ed. ed. Wiley, Hoboken, N.J. ; [Chichester].

Lochner, K., Kawachi, I., Kennedy, B.P., 1999. Social capital: a guide to its measurement. Health & Place 5, 259-270.

Marmot, M., 2010. Fair society, healthy lives. Strategic review of health inequalities in England post 2010. The Marmot Review, London.

Martin, J., Dubbert, P., 1982. Exercise applications and promortion in behavoral medicine: Current status and future directions. Journal of Consulting and Clinical Psychology 50, 14.

McGinn, A.P., Evenson, K.R., Herring, A.H., Huston, S.L., Rodriguez, D.A., 2008. The association of perceived and objectively measured crime with physical activity: a cross-sectional analysis. J Phys Act Health 5, 117-131.

National Center for Health Statistics, 2009. Health, United States,2008. http://www.ncbi.nlm.nih.gov/bookshelf/br.fcgi?book=healthus08 [accessed on August, 2010].

Office for National Statistics, 2010 ed.

Portes, A., 1998. Social Capital: Its Origins and Applications in Modern Sociology. Annual Review of Sociology 24, 1-24.

Portes, A., Landolt, P., 1996. The Downside of Social Capital. The American Prospect 26, 4.

Powell, K.E., Paffenbarger, R.S., 1985. Workshop on Epidemiologic and Public-Health Aspects of Physical-Activity and Exercise - a Summary. Public Health Reports 100, 118-126.

Putnam, R.D., 2000. Bowling alone : the collapse and revival of American community. Simon & Schuster, New York ; London.

Rubin, D.B., 1987. Multiple imputation for nonresponse in surveys. Wiley, New York ; Chichester.

Rubin, D.B., Schenker, N., 1991. Multiple imputation in health-care databases: an overview and some applications. Stat Med 10, 585-598.

Rutten, A., Abu-Omar, K., 2004. Prevalence of physical activity in the European Union. Sozial-Und Praventivmedizin 49, 281-289.

Schafer, J.L., 1997. Analysis of incomplete multivariate data. Chapman & Hall, London.

Stronegger, W.J., Titze, S., Oja, P., 2010. Perceived characteristics of the neighborhood and its association with physical activity behavior and self-rated health. Health & Place 16, 736-743.

Subramanian, S.V., Jones, K., Duncan, C., 2003. Multilevel methods for public health research, in: Kawachi, I., Berkman, L.F. (Eds.), Neighborhoods and health. Oxford University Press, New York, pp. 65-111.

Szreter, S., Woolcock, M., 2004. Health by association? Social capital, social theory, and the political economy of public health. International Journal of Epidemiology 33, 650-667.

The NHS Information Centre, L.S., 2010. Statistics on obesity, physical activity and diet: England, 2010. The Health and Social Care Information Centre.

Toutenburg, H., 1990. Rubin, D.B.: Multiple imputation for nonresponse in surveys. Statistical Papers 31, 180-180.

VicHealth, 2007. Barriers and Facilitators to Physical Activity for Older People in Culturally Diverse Communities.

Walberg, P., McKee, M., Shkolnikov, V., Chenet, L., Leon, D.A., 1998. Economic change, crime, and mortality crisis in Russia: regional analysis. BMJ 317, 312-318.

Warburton, D.E.R., Nicol, C.W., Bredin, S.S.D., 2006. Health benefits of physical activity: the evidence. Canadian Medical Association Journal 174, 801-809.

Wendel-Vos, W., Droomers, M., Kremers, S., Brug, J., van Lenthe, F., 2007. Potential environmental determinants of physical activity in adults: a systematic review. Obesity Reviews 8, 425-440.

Author Details

A multilevel analysis of the association between social networks and support on leisure time physical activity: evidence from 40 disadvantaged areas in London

Ge Yu PhD[*], **Adrian Renton** MD FFPH[*], **Elena Schmidt** PhD[*], **Patrick Tobi** MSc FMCPH[*], **Marcello Bertotti** PhD[*], **Paul Watts** MSc[*], **Shahana Lais** BSc[*]

[*] Institute for Health and Human Development, University of East London, Suite 250, University House, The Green, Water Lane, London E15 4LZ

Correspondence to: Dr Ge Yu Institute for Health and Human Development, University of East London, Suite 250, University House, The Green, Water Lane, London E15 4LZ. (Email: g.yu@uel.ac.uk; Tel +44 (0)208 223 4473)

Table(s)

Table 1 Scoring of social environment questions

Question item	Response/scoring
Social network	
How often you personally meet up with relatives How often you personally speak to relatives on the phone How often you personally write to relatives How often you personally meet up with friends How often you personally speak to friends on the phone How often you personally write to friends How often you personally speak to neighbours	Never=0 Less than once a month=1 Once or twice a month=2 Once a week or more=3 Most days=4
Social support	
How many people could you ask for help to go shopping if you are unwell How many people could you ask for help to lend you money to see you through the next few days How many people could you ask for help to give you advice and support in a crisis	None or Would not ask=0 One or two=1 More than two=2

Table2. Descriptive statistics (2-level models, outcome of low leisure time physical activity)

Outcome					
	MET-minutes/week	Median=1188		Missing (%) = 14.07	
Level 2, areas[a], n=40: LSOA-level predictors					
	IMD score	Mean=55.2		Range=42.42-70.59	
	Crime score	Mean=1.1		Range=-0.22-3.02	
	Combined living environment indicator	Mean=44.8		Range=21.03-76.17	
Level 1, individuals, n=4107: individual-level predictors, by outcome					
		Mean	95% CI		Missing (%)
Social network					
	Relative	7.25	7.16-7.35	*	4.82
	Friend	8.75	8.65-8.84	***	4.41
	Neighbour	2.63	2.59-2.68	**	2.73
		Frequency (*n*)	Proportion (%)		
Social Support					
Care support				***	3.85
	None	906	22.9		
	One or two	1872	47.4		
	More than two	1171	29.7		
Financial support				***	5.62
	None	1371	35.4		
	One or two	1506	38.8		
	More than two	999	25.8		
Informational support				***	4.70
	None	777	19.9		
	One or two	1763	45.0		
	More than two	1374	35.1		
Safety (daytime)				**	1.14
	Unsafe	297	7.3		
	Safe	3763	92.7		
Safety (night)				***	1.24
	Unsafe	1163	28.7		
	Safe	2893	71.3		
Age				***	9.86
	16-24	776	20.9		
	25-34	1018	27.5		
	35-44	807	21.8		
	45-54	454	12.3		
	55-64	288	7.8		
	>65	359	9.7		
Gender				***	1.75
	Male	1815	45.0		
	Female	2220	55.0		
Marital Status				***	2.65
	Never married	1800	45.0		
	Currently married	1666	41.7		
	Formerly married	532	13.3		

Education level				***	11.05
	Primary school	417	11.4		
	Secondary school	1223	33.5		
	A-Level or equivalent	969	26.5		
	Higher education	1044	28.6		
Personal Income				***	50.72
	£0-£399	706	34.9		
	£400-£1,249	742	36.7		
	£1,250+	576	28.4		
Job status				***	6.74
	Employed	1676	43.8		
	Unpaid housework	210	5.5		
	Full-time student	490	12.8		
	Unemployed	763	19.9		
	Retired	398	10.4		
	Disable/Illness	218	5.7		
	Other	75	1.9		

* p<0.1, ** p<0.05, *** p<0.01

a 40 LSOAs in London

Table 3 Incidence-rate ratios and 95% confidence intervals of predictors of LTPA, without (Model 1) and with (Model 2) area level predictors

	Model 1				Model 2			
	IRR		95% CI		IRR		95% CI	
Level 1, individuals, n=4107: individual-level predictors, by outcome								
Social network								
Relative	0.99		0.968	1.008	0.99		0.97	1.01
Friend	1.02	**	0.998	1.037	1.02	**	1.00	1.04
Neighbour	1.06	***	1.023	1.101	1.06	***	1.02	1.10
Social Support								
Care support								
None								
One or two	1.03		0.880	1.204	1.03		0.885	1.206
More than two	1.11		0.904	1.363	1.12		0.913	1.362
Financial support								
None								
One or two	0.94		0.814	1.078	0.93		0.809	1.078
More than two	0.91		0.756	1.091	0.91		0.754	1.090
Informational support								
None								
One or two	0.91		0.782	1.070	0.91		0.783	1.066
More than two	1.07		0.890	1.296	1.07		0.891	1.291
Safety (daytime)								
Unsafe								
Safe	0.97		0.819	1.153	0.97		0.708	1.337
Safety (night)								
Unsafe								
Safe	1.06		0.943	1.184	1.06		0.785	1.434
Age								
15-24	1.18	**	1.022	1.373	1.19	**	1.026	1.378
25-34								
35-44	0.90		0.784	1.040	0.90		0.782	1.038
45-54	0.95		0.803	1.131	0.95		0.803	1.132
55-64	0.86		0.694	1.059	0.86		0.696	1.064
>65	0.71	**	0.535	0.936	0.71	**	0.534	0.936
Gender								
Male								
Female	0.75	***	0.688	0.814	0.75	***	0.686	0.814
Marital Status								
Never married								
Currently married	0.89	**	0.796	1.000	0.89	**	0.794	1.000
Formerly married	1.08		0.934	1.251	1.08		0.933	1.247
Education level								
Primary school	0.85	*	0.707	1.010	0.85	*	0.705	1.014
Secondary school	1.09		0.969	1.235	1.10		0.974	1.242
A-Level or equivalent	1.08		0.953	1.218	1.08		0.956	1.224
Higher education								
Personal Income								
£0-£399	0.97		0.839	1.131	0.99		0.379	2.565
£400-£1,249								
£1,250+	1.01		0.877	1.170	0.74		0.324	1.689
Job status								
Employed								
Unpaid housework	0.77	**	0.626	0.945	0.77	**	0.621	0.949
Full-time student	0.86	**	0.749	0.988	0.86	**	0.745	0.983
Unemployed	0.88	*	0.773	1.012	0.89	**	0.775	1.016

Retired	0.71	*	0.494	1.009	0.70	**	0.494	1.004
Disable/Illness	0.43	***	0.286	0.662	0.43	***	0.284	0.664
Other	1.03		0.677	1.561	1.03		0.683	1.567
Level 2, areas, n=40: LSOA-level predictors								
IMD score					0.99		0.971	1.019
Crime score					0.70	**	0.663	1.306
Combined living environment indicator					1.02		1.000	1.034
safe1*crime					1.00		0.983	1.017
safe2*crime					1.01		0.991	1.020
income1*IMD					1.00		0.830	1.205
income3*IMD					1.00		0.779	1.272
community random variance	0.31	***			0.23	***		
rho	0.086				0.065			
Explained variance (%)	reference				25.81			

* p<0.1, ** p<0.05, *** p<0.01