

LONDON
SCHOOL of
HYGIENE
& TROPICAL
MEDICINE



LSHTM Research Online

Clark, C; Smuk, M; Cummins, S; Eldridge, S; Fahy, A; Lewis, D; Moore, DG; Smith, N; Taylor, SJC; Stansfeld, SA; (2017) An Olympic Legacy? Does the urban regeneration associated with the London 2012 Olympic Games impact on adolescent mental health? *American journal of epidemiology*, 187 (3). pp. 474-483. ISSN 0002-9262 DOI: <https://doi.org/10.1093/aje/kwx205>

Downloaded from: <http://researchonline.lshtm.ac.uk/4052675/>

DOI: <https://doi.org/10.1093/aje/kwx205>

Usage Guidelines:

Please refer to usage guidelines at <https://researchonline.lshtm.ac.uk/policies.html> or alternatively contact researchonline@lshtm.ac.uk.

Available under license: <http://creativecommons.org/licenses/by-nc-nd/2.5/>

<https://researchonline.lshtm.ac.uk>

An Olympic Legacy? Does the urban regeneration associated with the London 2012 Olympic Games impact on adolescent mental health?

Charlotte Clark¹, Melanie Smuk¹, Steven Cummins², Sandra Eldridge³, Amanda Fahy¹, Daniel Lewis²,
Derek G Moore⁴, Neil Smith¹, Stephanie JC Taylor³, Stephen A Stansfeld¹.

¹Centre for Psychiatry, Barts and the London School of Medicine, Queen Mary University of London, London, UK.

² Department of Social and Environmental Health Research, London School of Hygiene and Tropical Medicine, London, UK.

³Centre for Primary Care and Public Health, Barts and the London School of Medicine, Queen Mary University of London, London, UK.

4. School of Psychology, University of Surrey, Guildford, UK.

Contact Information

Dr Charlotte Clark PhD FACE CPsychol AFBPsS BSc (Hons)
Reader in Environmental & Mental Health Epidemiology
Centre for Psychiatry
Barts & the London School of Medicine
Queen Mary University of London
Old Anatomy Building
Charterhouse Square
London EC1M 6BQ
t: +44 (0)20 7882 2017
e: c.clark@qmul.ac.uk

Running head: Olympic Urban Regeneration and Mental Health

WORD COUNT: 3500/3500

Version 15/03/17

Please cite as: Clark, C; Smuk, M; Cummins, S; Eldridge, S; Fahy, A; Lewis, D; Moore, D; Smith, N; Taylor, S; Stansfeld, S (2017) An Olympic legacy? Does urban regeneration associated with the London 2012 Olympic Games impact on adolescent mental health? *American Journal of Epidemiology*

ABBREVIATIONS

MAR	Missing At Random
ORiEL	Olympic Regeneration in East London
RR	Relative Risk
WEMWBS	Warwick Edinburgh Mental Wellbeing Scale

ABSTRACT (200 words/200 words)

Public expenditure on mega-events such as the London 2012 Olympic Games is often justified by the potential legacy of urban regeneration and its associated health and wellbeing benefits for local communities. The ORiEL (Olympic Regeneration in East London) study examined whether urban regeneration associated with the 2012 Games was associated with improved mental health.

Adolescents aged 11-12 years attending schools in the Olympic host London Borough of Newham or in three adjacent comparison London Boroughs, completed a survey prior to the Olympic Games (2012) and six-months and 18-months after the Games (2013 and 2014, respectively). Change in depressive symptoms and wellbeing between baseline and each follow-up were examined. 2254 adolescents from 25 randomly selected schools participated. Adolescents from the Olympic host borough were more likely to have 'remained depressed' between baseline and the six-month and 18-month follow-ups (Relative Risk=1.78, 95%CI 1.12-2.83; Relative Risk=1.93, 95%CI 1.01-3.70), compared with adolescents from the comparison boroughs. No differences in wellbeing were observed. There was very little evidence that urban regeneration had any positive influence on adolescent mental health and some suggestion regeneration may have been associated with maintenance of depressive symptoms. Such programmes may have limited short-term impact on the mental health of adolescents.

Keywords: depressive symptoms, positive wellbeing; adolescent, urban regeneration, longitudinal

Public expenditure on sporting mega-events, such as the London 2012 Olympic Games, is often justified by the hypothesised positive impact of urban regeneration, including the provision of new sports and recreational facilities, related to hosting such events and the associated legacy benefits for local communities (1). Addressing deprivation by enhancing health and wellbeing through urban regeneration programmes was among the legacy benefits identified for the London 2012 Olympic Games (2). However, public health evaluations have thus far found little evidence for a positive impact of large-scale investment in urban regeneration at the household, dwelling, community or neighborhood level directly on mental health or indirectly on social determinants of mental health (3, 4). In fact, urban regeneration may negatively impact mental health (3-6) via increased stress associated with the environmental nuisance of regeneration (6), gentrification (5, 7), changes to social networks (8), displacement (1), loss of amenities (1), the lack of control over the planning process (1, 8), and an increase in relative deprivation amongst residents who do not benefit. Despite this, regeneration may impact positively on children and adolescents from these communities (7), via increasing feelings of safety, reducing exposure to stressors, and increasing access to amenities, yet few studies have evaluated the impact on the mental health and wellbeing of children and adolescents (4). The ORiEL (Olympic Regeneration in East London) study examined whether urban regeneration occurring around the 2012 London Olympic Games was associated with better adolescent mental health and wellbeing. We hypothesised that adolescents living in an area receiving the majority of Olympic-related urban regeneration would have greater positive change and better mental health six-months and 18-months post-regeneration, compared to adolescents living in comparison areas receiving less or no Olympic-related urban regeneration.

METHOD

Study design and participants

This longitudinal quasi-experimental study followed a cohort of adolescents over a three-year period, recruited from randomly selected schools in the London Boroughs of Barking & Dagenham, Hackney, Newham, and Tower Hamlets. The participants, in year 7 at baseline (age 11-12 years: Jan-June 2012), were first followed-up in year 8 (age 12-13 years: Jan-June 2013) six to 11 months after the completion of the London 2012 Games, and again in year 9 (age 13-14 years: Jan-June 2014) 18 to 23 months after the Games. Ethical approval was granted by the Queen Mary University of London Research Ethics Committee (QMREC2011/40), the Association of Directors of Children's Services (RGE110927) and the London Boroughs Research Governance Framework (CERGF113). Head teachers gave written consent for the study in their school; parents gave passive informed consent and could opt their child out of the study; adolescents gave written informed assent for the study.

Exposure to urban regeneration associated with the London 2012 Olympic Games

The intervention borough was the London Borough of Newham, where the London 2012 Olympic Games were mostly hosted and where the majority of regeneration occurred. Within the London Borough of Newham, regeneration associated with the Games was focused in three main areas; Stratford City Development; the Olympic Park; and the Olympic Fringe. The main components of this regeneration programme are outlined in Table 1. Although part of the retail complex (Westfield Stratford City) had opened in 2011-12 prior to baseline data collection, large areas where regeneration was taking place were inaccessible to the local communities from between 2008 to late 2012. For example, the Olympic Park development involved closing off the area from 2008 with it opening for a limited time only for ticket holders for the Olympics at the end of July 2012: the surrounding communities did not gain everyday access to the Olympic Park and its facilities until early 2013. Prior to 2008 much of the Olympic site was inaccessible derelict industrial land.

Three adjacent London Boroughs (Barking & Dagenham, Hackney, Tower Hamlets) were selected as comparison areas, hypothesised to benefit less from the planned regeneration, as they were more geographically distant from the Olympic Park and were not in direct receipt of the regeneration activities outlined in Table 1. Figure 1 shows the distribution of the schools across the four boroughs in East London.

Whilst selection of the intervention and comparison boroughs underpins the epidemiological design of the study, we additionally conducted analyses, using a different characterisation of 'exposure' to the urban regeneration associated with the London 2012 Olympic Games. This measure was the Euclidean distance of the participant's school to the Olympic Park calculated using a Geographical Information System (9). These analyses examined the odds for changes in mental health and wellbeing for an interquartile increase in distance to the Olympic Park (IQR=3240.7 meters).

Procedure

Of the 48 secondary schools in the four boroughs, we randomly selected six to seven schools in each borough: where a selected school refused to participate another school within the borough was randomly selected to participate. The study had 80% power to detect an 8% difference in well-being (5% significance level) with an 18-month follow-up sample of 1766 adolescents from 24 schools (10). This calculation was informed by a study (11) that found that wellbeing scores on a range of scales improved by 8-25% for adults and children after a neighborhood intervention. Twenty-five out of 41 invited schools participated (school response rate 60.9%) resulting in six intervention and 19 comparison schools). In seven schools, the entire Year 7 was invited to recruit >90 children per school. In the remaining schools a mixed-ability sample was selected. The socio-demographic characteristics of the baseline sample were similar to the 2011 National Census. Adolescents

completed a questionnaire in their classroom following a standardised protocol, which assessed wellbeing, mental health, physical activity, and sociodemographic factors.

Outcomes

Wellbeing and depressive symptoms were self-reported by the adolescents. The World Health Organisation defines well-being as “a state in which every individual realizes his or her own potential, can cope with the normal stresses of life, can work productively, and is able to make a contribution to her or his community” (12). Wellbeing was assessed by the Warwick-Edinburgh Mental Wellbeing Scale (WEMWBS) - a 14 item (5 response category) self-report measure of subjective positive wellbeing (13) at baseline and at the six-month and 18-month follow-ups. Pre-post absolute change in the continuous WEMWBS scores between baseline and the six-month and 18-month follow-up were calculated by subtracting the baseline score from the six-month or 18-month follow-up score, respectively.

Depressive symptoms were assessed by the Short Moods and Feelings Questionnaire, a 13 item (3 response category) self-report measure (14) valid for use with adolescents. The Short Moods and Feelings Questionnaire has been shown to discriminate a psychiatric sample from a pediatric control sample (14). Dichotomous scores (14) indicative of clinically relevant depressive symptoms were used to determine whether an adolescent had clinically relevant depressive symptoms at each timepoint (no depressive symptoms – score of 0-7 versus depressive symptoms – score ≥ 8). These dichotomous variables were then used to assess change between baseline and the six-month follow-up, and baseline and the 18-month follow-up, resulting in the following categorical outcomes: no depressive symptoms at baseline or follow-up (reference group), change from no depressive symptoms at baseline to depressive symptoms at follow-up ('became depressed'), change from

depressive symptoms at baseline to no depressive symptoms at follow-up ('no longer depressed'), and depressive symptoms at baseline and follow-up ('remained depressed').

Covariates available at baseline and both follow-ups were identified a priori from existing literature, which demonstrated cross-sectional and longitudinal associations with depressive symptoms in our previous East London school-based cohort study of adolescents (the RELACHS study- Research with East London Adolescents: Community Health Survey) conducted between 2001-2005 (15-18). The covariates were: age (months); gender; ethnicity (assessed using an 11 category variable based on the 2011 UK Census); number of years lived in the United Kingdom; number of parents lived with; parental income, bullied at school in the past 12-months, receiving free school meals (as a marker of social disadvantage), long-standing illness; number of life events, whether moved neighborhood since last survey; and the number of days since the Opening Ceremony of the Olympics that the questionnaire was completed. Social support from family and friends were assessed using the Multi-dimensional Scale of Perceived Social Support (19), with scores divided into tertiles, representing low-, medium- and high-support.

Statistical analyses

Weights were derived to take account of unequal probabilities of school and pupil selection.

Prevalence and missing data rates for the outcomes and covariates were examined: missing values ranged from 0.0% to 45.2%. We explored patterns and predictors of missing observations through logistic regression modelling. Analyses suggested that data was Missing At Random (MAR) (20). We imputed the data using multilevel multiple imputation in the REALCOM software (21), which uses a joint multivariate normal modelling approach through the Markov Chain Monte Carlo method. We imputed with 2 levels (1st=survey time (baseline, six-month follow-up or 18-month follow-up) and 2nd=adolescent) with all of the outcomes and covariates as fixed effects. Interaction terms between gender and the intervention, and free school meals and the intervention were also included. The

imputation model was chosen to be congenial (22) with the most saturated model of interest; auxiliary variables were included to strengthen the MAR assumption. We used a 'burn in' period of 25,000 iterations, followed by 50,000 iterations producing a dataset every 1000th iteration, resulting in 50 imputed datasets. The Markov Chain Monte Carlo chains were examined to check for convergence.

Analyses were carried out using STATA version 14 (23). Crude and adjusted linear, logistic and multinomial regression models were run to assess the impact of urban regeneration (intervention vs comparison) on short-term (wave 1 to wave 2) and longer-term change (wave 1 to wave 3) in wellbeing and depressive symptoms. The models were adjusted for baseline demographic factors; household factors; family and friend social support; and psychological factors (see Table 2 for variable details). An additional adjustment for baseline wellbeing (WEMWBS) was made to the adjusted model for wellbeing, to test sensitivity of the findings for baseline wellbeing. Interactions between urban regeneration (borough or distance to the Olympic Park) with gender and free schools meals were tested: with models stratified where interactions were $p \leq 0.05$. Inference sensitivity to departure from MAR was explored through tipping point sensitivity analysis where data was imputed under Missing Not At Random (MNAR) with increasing departure from the MAR assumption. Inferences were robust to departures from the MAR assumption.

RESULTS

Descriptives

Table 2 shows the prevalence for the outcomes and covariates at each time-point. 27.9% of the participants were from schools in the intervention borough and 72.1% from schools in the comparison boroughs. The distance of the participants' schools to the Olympic Park ranged from 1133 to 12,589 meters (interquartile range=3240.7 meters). Participants were ethnically diverse: the largest groups described themselves as White UK (16.9%), Asian Bangladeshi (14.9%), and White

Other (14.4%). Over one-fifth of the sample reported depressive symptoms at each time-point (baseline 21.8%; six-month follow-up 20.8%; 18-month follow-up 24.2%). The mean wellbeing score was 51 at each time-point.

Urban regeneration and depressive symptoms

Depressive symptoms were higher in the intervention borough at baseline compared with the comparison boroughs (27% vs 20%: unadjusted OR=1.49, P=0.024). Table 3 shows the changes in depressive symptoms between baseline and the six-month follow-up. Reflecting at least in part the higher prevalence of depression in the intervention borough at baseline, in the fully adjusted models, both adolescents who were 'no longer depressed' at the six-month follow-up (RR (Relative Risk)=1.53, 95%CI 1.07,2.20) or who 'remained depressed' at the six-month follow-up (RR=1.78, 95%CI 1.12,2.83) were more likely to be from the intervention borough than from the comparison boroughs.

Post-hoc restricted to those with baseline depression showed that adolescents from the intervention area were not more likely to have recovered at the six-month follow-up compared to those from the comparison area (Odds Ratio=0.72 95%CI 0.44-1.18). Indeed, amongst those with no baseline depression, adolescents from the intervention area were more likely to have become depressed at the six-month follow-up compared to those from the comparison area (Odds Ratio=1.42 95%CI 1.09,1.85).

Distance to the Olympic Park was not associated with changes in depressive symptoms between baseline and the six-month follow-up. There were no interactions between borough or distance to the Olympic Park and gender or eligibility for free school meals in relation to change in depressive symptoms between baseline and the six-month follow-up (P>0.05).

Table 3 shows the changes in depressive symptoms between baseline and the 18-month follow-up. In the fully adjusted models, adolescents who ‘remained depressed’ at the 18-month follow-up were more likely to be from the intervention borough than from the comparison boroughs (RR=1.93, 95%CI 1.01,3.70). Table 3 shows that distance to the Olympic Park was not associated with changes in depressive symptoms between baseline and the 18-month follow-up. No interactions were observed between borough or distance to the Olympic Park with gender or eligibility for free school meals in relation to change in depressive symptoms between baseline and the 18-month follow-up ($P>0.05$).

Post-hoc analyses showed that for those with no baseline depression, those from the intervention area were more likely to have become depressed at the 18-month follow-up compared to those from the comparison area (Odds Ratio=1.38 95%CI 1.06,1.80). For those with baseline depression, those from the intervention area were not more likely to have recovered at the 18-month follow-up (Odds Ratio=0.67 95%CI 0.41-1.10).

Urban regeneration and change in wellbeing

Wellbeing scores were lower in the intervention borough at baseline compared to the comparison boroughs (50.7 SE(0.6) vs 53.0 SE(0.2), $P=0.001$). There was little change in wellbeing scores between the surveys (baseline/six-month follow-up $\mu=-0.02$ SE 0.03; baseline/18-month follow-up $\mu=-0.04$ SE 0.04). Table 4 shows that there was no association between borough and change in wellbeing between baseline and either follow-up. Table 4 shows that distance to the Olympic Park was not associated with changes in wellbeing between baseline and the six-month follow-up or between baseline and the 18-month follow-up. No interactions were observed between borough or distance to the Olympic Park with gender or eligibility for free school meals in relation to change in wellbeing between baseline and the six-month follow-up or between baseline and the 18-month follow-up.

DISCUSSION

This study suggests that as a population health intervention (7, 24), the urban regeneration associated with the London 2012 Olympic Games had little or no detectable positive influence on changes in adolescent mental health in terms of depressive symptoms or wellbeing. Although those who were depressed at baseline were more likely to have improvement in their symptoms at six-months follow-up in the intervention compared to the control boroughs,, this was the only positive impact observed and should be considered in the light of more adolescents having depressive symptoms at baseline in the intervention borough. This association was not maintained 18-months post-regeneration nor replicated in other analyses. In fact, attending school in the intervention borough was associated with a greater chance of maintaining depressive symptoms. Our hypotheses that adolescents receiving urban regeneration would have greater positive change and better mental health post-regeneration, compared to adolescents receiving less or no urban regeneration were not supported in these data. These conclusions were further supported by analyses using a different characterisation of 'exposure' to the intervention: distance of the participant's school to the Olympic Park.

Urban regeneration and adolescent depressive symptoms

We found higher levels of depressive symptoms, in terms of 'remaining depressed' between baseline and both the six-month and the 18-month follow-ups, for adolescents living in the Olympic host borough receiving urban regeneration, replicating the findings of some previous studies of the impact of urban regeneration on adult populations (3, 4). There was evidence that regeneration was associated with becoming depressed for those with no baseline depression. Urban regeneration can be associated with increased feelings of social isolation (25), reduced social capital (25), increased

exposure to stress (26), and relative deprivation, all of which may influence mental health. Regeneration may not address residents' concerns (1, 5) and may not influence psychosocial, lifestyle, safety, or economic determinants of mental health (6, 27). Interviews with families in the ORiEL study found that during the Olympic event residents in the intervention borough felt that their environment was safer and more unified, but that they appreciated that this was a temporary effect, with little impact on more immediate concerns such as poor housing and opportunities for employment (28). However, the intervention borough had higher rates of depressive symptoms at baseline and at both follow-ups compared with the comparison boroughs, which may be explained by other unmeasured differences between the boroughs such as social, economic and environmental determinants of mental health (6, 27) including income, employment, physical activity, and diet. Whether these determinants are impacted by urban regeneration is being explored in a study of the ORiEL adolescents' parents. Borough-level differences in depressive symptoms may partially account for the findings reported here. A study of adolescents in three of the London Boroughs included in the ORiEL study - the London Boroughs of Newham, Tower Hamlets and Hackney, carried out between 2001-2005 found the highest rates of depressive symptoms in Hackney and the lowest rates in Newham (29): suggesting that borough differences in rates of mental health are changeable over relatively short time periods.

The association between living in the Olympic host borough and a greater likelihood of remission of depressive symptoms at six- but not 18-months may reflect temporary positive impacts associated with regeneration (28). However, this finding may also reflect selection into this outcome group by baseline depressive symptoms. We could not replicate the association of borough on remission from depressive symptoms in analyses restricted to those with baseline depression, which may indicate chance findings.

In contrast to the findings characterising exposure to the urban regeneration by borough, we found that distance of the participant's school from the Olympic Park was not associated with change in depressive symptoms between baseline and the six-month or the 18-month follow-up. This difference in findings may reflect the more robust methodology in the ORiEL study for examining regeneration by borough than by distance to the Olympic Park, as the sample were selected on borough.

Urban regeneration and adolescent wellbeing

There were no differences in change in wellbeing between the intervention and comparison boroughs or by distance to the Olympic Park, suggesting no positive impact of Olympic-related regeneration on wellbeing. In our analyses few factors predicted positive or negative change in wellbeing, which may be because we observed little change in wellbeing over time. Negative change was most strongly associated with baseline wellbeing. A recent systematic review of interventions using the WEMWBS measure of wellbeing found large variability in change scores for different interventions (30) but few studies had examined the impact of neighborhood interventions. Our study, along with one study of adults (31) suggest that the WEMWBS may not be particularly sensitive to change for evaluating neighborhood population health interventions. In our population wellbeing appeared to be more of a stable trait than a changing state (32).

Limitations & strengths

Exposure to Olympic-led regeneration was determined by school location, which may have resulted in some exposure misclassification. It is difficult to characterise the exact dose, or when regeneration begins and ends for regeneration associated with mega-events like the Olympic Games: a small degree of regeneration may have started prior to our baseline survey and have continued beyond our 18-month follow-up. There may be contamination between the intervention and comparison boroughs due to geographical proximity. Deprivation varied little between schools:

however, area-level confounding by deprivation may remain. The regeneration was highly localised resulting in much of the London Borough of Newham remaining unchanged. Further, demographic changes in East London in the past decade such as increases in population, ethnic diversity, and the private-renting of flats could also have influenced the findings. Positive impacts of urban regeneration on mental health may be demonstrated over a longer-time period or may have been observed immediately after the Olympic event itself, but this was not tested in this study. This study reports analyses that characterise urban regeneration as a holistic event: further on-going analyses will examine specific neighbourhood environmental changes associated with the regeneration activities such as access to greenness and walkability and associations with health (33).

Strengths include the large representative sample indicative of the ethnic super-diversity in East London. This is one of the first studies to examine the longitudinal associations of urban regeneration on the mental health of an adolescent population. The study has high response rates; overcoming a key limitation of many previous studies (4). Few participants relocated during the study, attrition was low, and multiple imputation was employed to deal with missing data.

Implications

In conclusion, complex public health interventions like urban regeneration are very challenging to evaluate (7, 33). This large-scale quasi-experimental study provides little evidence that the urban regeneration associated with the London 2012 Games had a positive impact on adolescent mental health in terms of depressive symptoms or wellbeing. In fact, urban regeneration may have maintained depressive symptoms but this may be explained by differences between boroughs in the social and economic determinants of mental health. The predicted legacy benefit of the London 2012 Games on enhancing wellbeing (2) was not observed here. Regeneration may have maintained and contributed to the onset of depressive symptoms. Any beneficial effects of regeneration may be elusive or may take longer to appear.

Acknowledgements

1) Centre for Psychiatry, Barts and the London School of Medicine, Queen Mary University of London (Charlotte Clark, Melanie Smuk, Amanda Fahy, Neil Smith, Stephen A Stansfeld). Centre for Primary Care and Public Health, School of Medicine, Queen Mary University of London (Sandra Eldridge, Stephanie JC Taylor). Department of Social & Environmental Health Research, London School of Hygiene and Tropical Medicine (Steven Cummins, Daniel Lewis). School of Psychology, University of Surrey (Derek G Moore).

2) All authors have contributed equally to the work presented in this paper.

3) This work was funded by the National Institute for Health Research Public Health Research Board (Grant number 09/3005/09). The funders of the study had no role in the study design, data collection, data analysis, data interpretation or writing of the report.

4) We would like to thank members of the ORiEL (Olympic Regeneration in East London) study research team including Dr Ellen Flint, Dr Mark Petticrew, Dr Adrian Renton, Vanathi Tharmaratnam, Dr Claire Thompson, Danielle House, Shaneka Foster, Bukola Thompson, Rebecca Evans, Lianne Austin, Janat Hossain and all other team members who helped with the study.

8) The authors have no conflicts of interest to report.

REFERENCES

1. Clark J, Kearns A, Cleland C. Spatial scale, time and process in mega-events: the complexity of host community perspectives on neighbourhood change. *Cities Environ* 2016;53:87-97.
2. Host Boroughs Joint Committee. Strategic Regeneration Framework: an Olympic legacy for the host boroughs. London: Published by the London Boroughs of Greenwich, Hackney, Newham, Tower Hamlets & Waltham Forest
<http://www.gamesmonitor.org.uk/files/strategic-regeneration-framework-report.pdf>, 2009.
3. Thomson H, Atkinson R, Petticrew M, et al. Do urban regeneration programmes improve public health and reduce health inequalities? A synthesis of the evidence from UK policy and practice (1980-2004). *J Epidemiol Community Health* 2006;60(2):108-115.
4. Clark C, Myron R, Stansfeld S, et al. A systematic review of the evidence on the effect of the built and physical environment on mental health. *Journal of Public Mental health* 2007;6(2):14-27.
5. Huxley P, Evans S, Leese M, et al. Urban regeneration and mental health. *Soc Psychiatry Psychiatr Epidemiol* 2004;39(4):208-285.
6. Thomas R, Evans S, Huxley P, et al. Housing improvement and self-reported mental distress among council estate residents. *Soc Sci Med* 2005;60(12):2773-2783.
7. Bond L, Egan M, Kearns A, et al. GoWell: The challenges of evaluating regeneration as a population health intervention. *Prev Med* 2013;57(6):941-974.
8. Halpern D. *Mental health and the built environment*. London, UK: Taylor & Francis; 1995.
9. ESRI. ArcGIS 10.3. Redlands, CA: Environmental Systems Research Institute 2014.
10. Smith NR, Clark C, Fahy AE, et al. The Olympic Regeneration in East London (ORiEL) study: protocol for a prospective controlled quasi-experiment to evaluate the impact of urban regeneration on young people and their families. *BMJ Open* 2012;2(e001840).
11. Leventhal T, Brooks-Gunn J. Moving to opportunity: an experimental study of neighbourhood effects on mental health. *Am J Public Health* 2003;93(9):1576-1582.
12. W.H.O. Promoting Mental Health; Concepts emerging evidence and practice. Summary report. Geneva: World Health Organisation., 2004.
13. Stewart-Brown S, Tennant A, Tennant R, et al. Internal construct validity of the Warwick-Edinburgh Mental Well-being Scale (WEMWBS): a Rasch analysis using data from the Scottish Health Education Population Survey. *Health and Quality of Life Outcomes* 2009;19(7):15.
14. Angold A, Costello EJ, Messer SC, et al. Development of a short questionnaire for use in epidemiological studies of depression in children and adolescents. *Int J Meth Psych Res* 1995;5:237-249.
15. Stansfeld SA, Haines MM, Head JA, et al. Ethnicity, social deprivation and psychological distress in adolescents: school-based epidemiological study in East London. *Br J Psychiatry* 2004;185(3):233-238.
16. Klineberg E, Clark C, Bhui KS, et al. Social support, ethnicity and mental health in adolescents. *Soc Psychiatry Psychiatr Epidemiol* 2006;41(9):755-760.
17. Fagg J, Curtis S, Clark C, et al. Neighbourhood perceptions among inner-city adolescents: Relationships with their individual characteristics and with independently assessed neighbourhood conditions. *J Environ Psychol* 2008;28(2):128-142.
18. Rothon C, Head J, Klineberg E, et al. Can social support protect bullied adolescents from adverse outcomes? A prospective study on the effects of bullying on the educational achievement and mental health of adolescents at secondary schools in East London. *J Adolesc* 2011;34(3):579-588.
19. Zimet GD, Dahlem NW, Zimet SG, et al. The multidimensional scale of perceived social support. *J Pers Assess* 1988;52:30-41.
20. Rubin DB. *Multiple Imputation for Nonresponse in Surveys*. New York, NY.: John Wiley and Sons; 1987.

21. REALCOM-IMPUTE Software for Multilevel Multiple Imputation with Mixed Response Types University of Bristol, Bristol, United Kingdom.
22. Meng XL. Multiple-imputation inferences with uncongenial sources of input (with discussion). *Statistical Science* 1994;9(4):538-573.
23. StataCorp. Stata Statistical Software: Release 14. College Station, TX: StataCorp LP, 2015.
24. Craig P, Cooper C, Gunnell D, et al. Using natural experiments to evaluate population health interventions: new Medical Research Council guidance. *J Epidemiol Community Health* 2011;66(12):1182-1186.
25. Rogers A, Huxley P, Evans S, et al. More than jobs and houses: mental health, quality of life and the perceptions of locality in an area undergoing urban regeneration. *Soc Psychiatry Psychiatr Epidemiol* 2008;43(5):364-372.
26. Thomas RW, Evans S, Gately C, et al. State-event relations among indicators of susceptibility to mental distress in Wythenshawe in the UK. *Soc Sci Med* 2002;55(6):921-935.
27. Kearns A, Mason P. Regeneration, relocation and health behaviours in deprived communities. *Health and Place* 2015;32:43-58.
28. Thompson C, Lewis DJ, Greenhalgh T, et al. "Everyone was looking at you smiling": East London residents' experiences of the 2012 Olympics and its legacy on the social determinants of health. *Health and Place* 2015;36:18-24.
29. Institute of Community Health Sciences. *Health of young people in East London*. Norwich, UK: The Stationary Office; 2003.
30. Maheswaran H, Weich S, Powell J, et al. Evaluating the responsiveness of the Warwick Edinburgh Mental Well-Being Scale (WEMWBS): group and individual level analysis. *Health and Quality of Life Outcomes* 2012;10(1):156.
31. Phillips G, Bottomley C, Schmidt E, et al. Well London Phase-1: results among adults of a cluster-randomised trial of a community engagement approach to improving health behaviours and mental well-being in deprived inner-city neighbourhoods. *J Epidemiol Community Health* 2014;68(7):606-614.
32. Ormel J. Neuroticism and well-being inventories: measuring traits or states? . *Psychol Med* 1983;13(1):165-176.
33. Humphreys DK, Panter J, Sahlqvist S, et al. Changing the environment to improve population health: a framework for considering exposure in natural experimental studies. *J Epidemiol Community Health* 2016;2016(0):1-6.

Table 1: Main regeneration components associated with the London 2012 Olympic Games in the London Borough of Newham, UK

Date	Area	Main Components
2011-12	Stratford City Development	Retail and leisure centre comprising 1.9 million sq ft of retail space (inc. Westfield Stratford City), 500,000 sq ft of office and business space, new civic and public space
2012-14	Olympic Park	The Olympic Park consists of 246 hectares of regenerated land which consists of: new green spaces and parkland, public space and play areas, world class sports venues (main stadium, aquatics centre, velodrome, BMX & mountain bike tracks, road cycle route) and associated facilities, improved physical connectivity and accessibility to the Olympic park from surrounding areas (foot & cycle paths, bridges, waterways, road and rail links). New housing associated with the former Athletes village (East Village)
2012-14	Olympic Fringe	Fringe surrounding the Olympic Park will receive 90 hectares of improved green/civic space and improved connectivity to the main Olympic Park

Baseline: January-June 2012; First follow-up January-June 2013; Second follow-up January-June 2014.

Table 2: Descriptive statistics for key intervention, outcome, demographic, household, social support and psychological measures at each survey for the ORiEL study, London UK (2011-2014).

	Baseline survey			Six-month follow-up survey			18-month follow-up survey		
	n	%	Missing %	n	%	Missing %	n	%	Missing %
INTERVENTION/EXPOSURE									
Intervention	2254		0.0						
Comparison boroughs	1626	72.1							
Newham borough	628	27.9							
OUTCOME MEASURES									
Short Moods and Feelings Questionnaire	2068		8.2	2116		6.1	2155		4.4
Not Depressed	1618	78.2		1676	79.2		1633	75.8	
Depressed (>=8)	450	21.8		440	20.8		522	24.2	
Scale reliability ^a	0.87			0.90			0.91		
Warwick-Edinburgh Mental Wellbeing Scale	1943		13.8	2016		10.6	2085		7.5
Scale score ^b		51.2 (9.0)			51.6 (9.7)			51.2 (10.1)	
Scale reliability ^a		0.84			0.88			0.90	
BASELINE DEMOGRAPHIC MEASURES									
Gender	2254		0.0						
Male	1271	56.4							
Female	983	43.6							
Ethnicity	2254		0.0						
White: UK	380	16.9							
White: Other	326	14.4							
White: Mixed	190	8.4							
Asian: Indian	85	3.8							
Asian: Pakistani	86	3.8							
Asian: Bangladeshi	337	14.9							

Asian: Other	72	3.2	
Black: Caribbean	111	4.9	
Black: African	249	11.0	
Black: Other	263	11.7	
Other	155	7.0	
Time in the UK	2221		1.5
All my life	1629	73.3	
Over 10 years	174	7.8	
6-10 years	190	8.6	
Less than 6 years	228	10.3	
Long Term Illness	2153		4.5
No	1898	88.2	
Yes	255	11.8	

HOUSEHOLD MEASURES

Parental Income	1984		12.0	2104		6.7	2090		7.3
Two	796	40.1		813	38.6		832	39.8	
One	832	41.9		883	42.0		891	42.6	
None	356	18.0		408	19.4		367	17.6	
Household Composition	2221		1.5	2234		0.9	2238		0.7
Lives with both parents	1503	67.7		1544	69.1		1510	67.5	
Lives with 1 parent	673	30.3		643	28.8		688	30.7	
Lives with no parent	45	2.0		47	2.1		40	1.8	
Moved neighborhood in past year (baseline) or since previous survey	1914		15.1	2137		5.2	2167		3.9
No	1746	91.2		1977	92.5		2022	93.3	
Yes	168	8.8		160	7.5		145	6.7	
Free School Meals	2208		2.0	2214		1.8	2219		1.5
No	1376	62.3		1404	63.4		1503	67.7	
Yes	832	37.7		810	36.6		716	32.3	

SOCIAL SUPPORT MEASURES

Multi-dimensional Scale of Perceived Social Support - Family

	1236		45.2	1663		26.2	1962		13.0
Low Tertile	378	30.6		530	31.9		642	32.7	
Medium Tertile	392	31.7		475	28.6		586	29.9	
High Tertile	466	37.7		658	39.5		734	37.4	

Multi-dimensional Scale of Perceived Social Support - Friend

	1239		45.0	1656		26.5	1958		13.1
Low Tertile	349	28.2		495	29.9		649	33.1	
Medium Tertile	470	37.9		592	35.7		634	32.4	
High Tertile	420	33.9		569	34.4		675	34.5	

PSYCHOLOGICAL MEASURES

Ever Bullied	1463		35.1						
No	948	64.8							
Yes	515	35.2							
Negative Life Events	1663		26.2	1910		15.3	2001		11.2
0	865	52.0		691	36.2		481	24.0	
1	373	22.5		469	24.5		499	25.0	
2	235	14.1		334	17.5		372	18.6	
3+	190	11.4		416	21.8		649	32.4	
Long Term Illness	2153		4.5						
No	1898	88.2							
Yes	255	11.8							

^a Values are expressed as Cronbach's α . ^b Values are expressed as mean (standard deviation)

Table 3: Associations of urban regeneration with change in depressive symptoms (baseline to six-month follow-up and baseline to 18-month follow-up) for the ORiEL study, London UK (2011-2014).

	Became depressed ^c				No longer depressed ^c				Remain depressed ^c			
	Unadjusted		Adjusted ^d		Unadjusted		Adjusted ^d		Unadjusted		Adjusted ^d	
	RR	95%CI	RR	95%CI	RR	95%CI	RR	95%CI	RR	95%CI	RR	95%CI
Baseline to six-month follow-up												
Intervention Borough ^a	1.32	0.81, 2.12	1.44	0.95, 2.17	1.44 ^e	1.03, 2.02	1.53 ^e	1.07, 2.20	1.70 ^e	1.04, 2.77	1.78 ^e	1.12, 2.83
Distance to Olympic Park ^b	1.08	0.95, 1.23	0.96	0.81, 1.15	1.10	0.95, 1.27	1.04	0.89, 1.20	1.02	0.89, 1.16	0.88	0.72, 1.07
Baseline to 18-month follow-up												
Intervention Borough ^a	1.23	0.82, 1.83	1.30	0.97, 1.76	1.53 ^e	1.07, 2.17	1.39	0.88, 2.18	1.57	0.83, 2.95	1.93 ^e	1.01, 3.70
Distance to Olympic Park ^b	1.16 ^e	1.02, 1.31	1.05	0.89, 1.23	1.03	0.89, 1.20	1.03	0.85, 1.25	1.12	0.96, 1.29	0.99	0.76, 1.29

^aIntervention Borough = London Borough of Newham versus the three comparison London Boroughs of Hackney, Tower Hamlets, and Barking and Dagenham.

^bDistance to Olympic Park is estimate per interquartile increase in distance (meters).

^cReference group for the outcome is 'remain not depressed'.

^dAdjusted for gender, age, ethnicity, length of time lived in the UK, no of days since the Olympics, parental income, no of parents live with, whether moved neighborhood since baseline, eligible for free school meals, family social support, friend social support, bullying, negative life events, long-term illness.

^ep<0.05

Table 4: Associations of urban regeneration with change in wellbeing (baseline to six-month follow-up and baseline to 18-month follow-up) for the ORiEL study, London UK (2011-2014).

	Baseline to 6-month follow-up						Baseline to 18-month follow-up					
	Unadjusted		Adjusted ^c		Adjusted ^c + baseline WEMWBS		Unadjusted		Adjusted ^c		Adjusted ^c + baseline WEMWBS	
	Co-efficient	95%CI	Co-efficient	95%CI	Co-efficient	95%CI	Co-efficient	95%CI	Co-efficient	95%CI	Co-efficient	95%CI
Intervention Borough ^a	0.58	-1.21, 2.36	0.18	-1.45, 1.80	-0.50	-1.86, 0.85	1.23	-0.74, 3.20	0.52	-0.95, 1.99	-0.07	-1.59, 1.44
Distance to Olympic Park ^b	-0.18	-0.93, 0.57	0.01	-0.76, 0.78	0.31	-0.20, 0.81	-0.60	-1.46, 0.26	-0.01	-0.72, 0.70	0.11	-0.39, 0.62

^aIntervention Borough = London Borough of Newham versus the three comparison London Boroughs of Hackney, Tower Hamlets, and Barking and Dagenham.

^bDistance to Olympic Park is estimate per interquartile increase in distance (meters).

^c Adjusted for gender, age, ethnicity, length of time lived in the UK, no of days since the Olympics, parental income, no of parents live with, whether moved neighborhood since baseline, eligible for free school meals, family social support, friend social support, bullying, negative life events, long-term illness.