



OPEN ACCESS

# Evaluating the effect of change in the built environment on mental health and subjective well-being: a natural experiment

Bina Ram <sup>1</sup>, Elizabeth S Limb <sup>1</sup>, Aparna Shankar <sup>1</sup>, Claire M Nightingale <sup>1</sup>, Alicja R Rudnicka <sup>1</sup>, Steven Cummins <sup>2</sup>, Christelle Clary,<sup>2</sup> Daniel Lewis,<sup>2</sup> Ashley R Cooper <sup>3,4</sup>, Angie S Page,<sup>4</sup> Anne Ellaway <sup>5</sup>, Billie Giles-Corti <sup>6</sup>, Peter H Whincup <sup>1</sup>, Derek G Cook <sup>1</sup>, Christopher G Owen <sup>1</sup>

► Additional material is published online only. To view please visit the journal online (<http://dx.doi.org/10.1136/jech-2019-213591>).

For numbered affiliations see end of article.

## Correspondence to

Dr Bina Ram, Population Health Research Institute, St George's, University of London, London SW17 0RE, UK; [bram@sgul.ac.uk](mailto:bram@sgul.ac.uk) and Professor Christopher G Owen; [cowen@sgul.ac.uk](mailto:cowen@sgul.ac.uk)

Received 1 December 2019  
Revised 9 March 2020  
Accepted 31 March 2020

## ABSTRACT

**Background** Neighbourhood characteristics may affect mental health and well-being, but longitudinal evidence is limited. We examined the effect of relocating to East Village (the former London 2012 Olympic Athletes' Village), repurposed to encourage healthy active living, on mental health and well-being.

**Methods** 1278 adults seeking different housing tenures in East village were recruited and examined during 2013–2015. 877 (69%) were followed-up after 2 years; 50% had moved to East Village. Analysis examined change in objective measures of the built environment, neighbourhood perceptions (scored from low to high; quality –12 to 12, safety –10 to 10 units), self-reported mental health (depression and anxiety) and well-being (life satisfaction, life being worthwhile and happiness) among East Village participants compared with controls who did not move to East Village. Follow-up measures were regressed on baseline for each outcome with group status as a binary variable, adjusted for age, sex, ethnicity, housing tenure and household clustering (random effect).

**Results** Participants who moved to East Village lived closer to their nearest park (528 m, 95% CI 482 to 575 m), in more walkable areas, and had better access to public transport, compared with controls. Living in East Village was associated with marked improvements in neighbourhood perceptions (quality 5.0, 95% CI 4.5 to 5.4 units; safety 3.4, 95% CI 2.9 to 3.9 units), but there was no overall effect on mental health and well-being outcomes.

**Conclusion** Despite large improvements in the built environment, there was no evidence that moving to East Village improved mental health and well-being. Changes in the built environment alone are insufficient to improve mental health and well-being.

## INTRODUCTION

Mental health disorders are recognised as a leading global cause of disease.<sup>1</sup> They are the leading cause of disability-adjusted life years and the third leading cause of overall disease burden.<sup>2</sup> In 2017, approximately 264 million people (2%–6%) worldwide experienced depression and 284 million (2.5%–7%) experienced anxiety, making these the most prevalent mental health disorders.<sup>3</sup> In the UK, around one in six people report depression and/or anxiety,<sup>4</sup> and these mental health disorders are increasing despite modest improvements in well-being.<sup>5</sup>

There is growing interest in the effect of the built environment on health, especially with the increasing number of people living in cities rather than rural environments.<sup>6</sup> Living in cities can have adverse effects on health outcomes through overcrowding, heavy traffic, fear of crime and lack of green space.<sup>7</sup> Exposure to such adverse environments may be greater among the more disadvantaged, which might propagate social inequalities, where those less privileged have poorer quality of life, mental health and well-being.<sup>8–9</sup> The mechanism by which the built environment might affect mental health and well-being are complex, with both direct and indirect pathways proposed. Direct pathways include factors such as noise and traffic,<sup>10</sup> while indirect pathways include neighbourhood social cohesion that may create positive social processes enhancing better mental health.<sup>11</sup> However, there is limited high-quality evidence available to establish the contribution these different pathways potentially make.<sup>12</sup> While a number of studies have suggested that the built environment might affect mental health and well-being, these are largely cross-sectional studies or uncontrolled longitudinal studies.<sup>12–13</sup> These study designs raise concerns over selection bias, due to poor participation rates and intrinsic differences between those who live in better neighbourhoods and those who do not (reasons for which can be multifactorial and complex). In the case of longitudinal studies, there is inadequate control for underlying health behaviour trends in the population at large<sup>12</sup>; therefore causality cannot be assumed. High-quality longitudinal evidence, especially that which is generated from natural experiments, which evaluate the health effects of major changes in the built environment are needed.<sup>12</sup> Unfortunately, there are few studies of this type, and fewer still have considered mental health and well-being outcomes.<sup>14–17</sup> The limited evidence shows no clear indication of the effect of the built environment or urban regeneration on mental health and well-being. Furthermore, the role of effect modification by socioeconomic factors, which would inform how changing the built environment can address health inequalities, remains largely unknown.

The East Village neighbourhood, the former London 2012 Olympics Athletes' Village, offered a unique opportunity to evaluate a natural



© Author(s) (or their employer(s)) 2020. Re-use permitted under CC BY-NC. No commercial re-use. See rights and permissions. Published by BMJ.

**To cite:** Ram B, Limb ES, Shankar A, et al. *Journal of Epidemiology & Community Health* Epub ahead of print: [please include Day Month Year]. doi: 10.1136/jech-2019-213591

experiment. East Village is a purpose-built mixed-use residential development, which was designed to encourage healthy active living.<sup>14</sup> Adults seeking to move into one of three different tenured types of accommodation in East Village (social, intermediate/affordable and market-rent; intermixed within blocks with similar physical access to amenities) were recruited and followed-up after 2 years when half had relocated to East Village.<sup>14</sup> The present study investigates whether changes in objective measures of the built environment and in subjective perceptions of the residential neighbourhood are associated with change in mental health and well-being, and whether any changes are equitable across housing tenures.

## METHODS

### Study design

The Examining Neighbourhood Activities in Built Living Environments in London (ENABLE London) Study was a controlled prospective cohort study designed to examine the effect of moving to East Village, a repurposed new-built residential neighbourhood created using active design principles. Each participant was followed over a 2-year period including pre-assessment (prior to the move) and post-assessment, by which time half the cohort had moved into East Village. Crucially, this enabled comparison of the health effect of moving to East Village, compared with not moving or moving elsewhere. Assessment of effects on physical activity has been published elsewhere.<sup>14</sup> In this article, the main outcomes were mental health and well-being. The study was approved by the City Road and Hampstead Ethical Review Board (REC ref number 12LO1031). Full details of the study design have been published elsewhere.<sup>18</sup>

### Study population

Adults (aged 16 years and over) seeking to move into three different housing tenures in East Village were recruited: (i) social housing (for those on the council social housing register receiving housing benefits); (ii) intermediate/affordable accommodation (including shared-ownership, shared equity and affordable market-rent, the latter provided by housing associations at a cost of up to 80% of the average rent for local private lettings) and (iii) market rent (private rentals). Eligibility involved financial checks by the relevant housing associations, and adults were therefore grouped into housing tenure being sought, as this reflected household income. Other adults living within the same households were also invited to take part. Social housing participants were largely from the East London Borough of Newham, while those seeking intermediate and market rent were also mainly from East London, with some dispersed around Greater London.<sup>18</sup> Baseline examinations took place during January 2013 to January 2016, and follow-up examinations (identical to baseline) were at 24 months after initial enrolment. All participants gave written informed consent.

## OUTCOMES

### Objective characteristics of the built environment

Characteristics of the neighbourhood at baseline and follow-up were derived using Geographic Information System (GIS) data at baseline and follow-up for households living in the Greater London area. These included street-network distance from home to closest park,<sup>19</sup> public transport access,<sup>20</sup> and a measure of neighbourhood walkability calculated within a 1 km street network home-centred buffer. Neighbourhood walkability is

a relative index derived from a composite score of land-use mix (a measure of the heterogeneity of distribution of surface of residential, commercial, office, entertainment and institutional land), street connectivity (from the number of three or more branch road junctions per street-kilometre) and residential density.

### Neighbourhood perceptions

Fourteen items assessed the perceptions of the neighbourhood environment at baseline and were repeated at follow-up.<sup>21</sup> Items were taken from several validated questionnaires including Health Survey for England, How Areas in Brisbane Influence health and ActiviTY (HABITAT), Neighbourhood Environment Walkability Scale (NEWS) and RESIDENTIAL Environment (RESIDE) study. Full details have been provided elsewhere.<sup>21</sup> Each item was rated on a 5-point Likert Scale from 'strongly agree' to 'strongly disagree'. Exploratory factor analysis at baseline derived two neighbourhood perception scales<sup>21</sup>: five items assessed neighbourhood 'safety' and six items assessed neighbourhood 'quality'. Internal reliability for each of the scales was assessed using Cronbach's alpha; both scales showed good internal reliability ('safety' 0.87 and 'quality' 0.78). Three items were excluded as they did not load strongly onto either of the two factors. Scores for each item were summed to create two scales, 'crime' scale ranging from -10 (more crime) to +10 (less crime) and 'quality' scale ranging from -12 (poor neighbourhood quality) to +12 (better neighbourhood quality). Thus, higher scores indicated positive neighbourhood perceptions (ie, safety/less crime and better neighbourhood quality). The scores were recalculated at follow-up using the baseline weightings.

### Mental health (anxiety and depression) and well-being

The Hospital Anxiety and Depression Scale (HADS) measured anxiety and depression.<sup>22</sup> Seven items assessed depression, and seven items assessed anxiety. Each item was scored between 0 and 3 and summed providing a maximum score of 21 for each subscale; higher scores indicate poorer mental health. The reliability and validity of the HADS has been demonstrated in a variety of settings beyond hospital practice for which it was designed, including primary care patients and the general population.<sup>23 24</sup> Three measures of subjective well-being included life satisfaction, feeling life is worthwhile and feeling happy yesterday<sup>25</sup> and were rated on a scale from 1 (not at all) to 10 (extremely); higher scores indicate positive well-being.

### Covariates

Demographic data included age group (16 to 24 years, 25 to 34 years, 35 to 49 years and 50+ years), sex and ethnic group (White, Asian, Black and Mixed/Other). Household composition was assessed as the total number of people in the household, living with a partner and living with children. Other covariates included level of education ('degree or higher', 'intermediate qualification' 'other/none'), and work status 'employed', 'unemployed' (those seeking work or on a Government work scheme) and 'economically inactive' (including students, retired, unable to work due to ill health or looking after home/family). Of those employed, the three-level National Statistics Socio-Economic Classification (NS-SEC) of 'higher/managerial', 'intermediate' and 'routine/manual' occupations was used. Analyses were controlled for the presence of a limiting longstanding illness (LLI), which defined 'health status'.

## Statistical methods

Multilevel linear regression models were fitted to examine the effect of moving to East Village on built environment characteristics, neighbourhood perceptions, levels of mental health and well-being compared with those who did not move to East Village (control group). Outcome at follow-up was regressed on baseline outcome, adjusting for East Village or control group as a fixed effect and household as a random effect to allow for household clustering. Further models adjusted for age group, sex and ethnic group (other sociodemographic factors were not included as they were strongly associated with housing tenure). An interaction term between East Village/control group, and housing tenure was also included to assess if housing tenure acted as an effect modifier (ie, the effect of moving to EV on mental health differed by housing tenure). Sensitivity analyses were carried out comparing East Village participants with controls who remained at their baseline address at follow-up and controls who had moved elsewhere, and by limiting the analyses to those who were followed-up within 28 days of the target 2-year follow-up date. The impact of missing data at follow-up for depression, anxiety, life satisfaction, feeling life is worthwhile and feeling happy yesterday was assessed using Stata *mi impute* commands to impute data at follow-up conditional on the model variables (baseline outcome, East Village/control group, age group, sex, ethnic group and housing tenure). All analyses were carried out using STATA/SE software (Stata/SE 15 for Windows; StataCorp LP, College Station, TX, USA).

## RESULTS

Participants were recruited at baseline in three phases, determined by the staggered release of accommodation by housing tenure between January 2013 and January 2016. A total of 1819 households were invited, and 1278 adults from 1006 households (55% of households) participated at baseline, of whom 520 (41%) were seeking social housing, 524 (41%) intermediate housing and 234 (18%) market-rent housing. Two years after baseline assessments (median 105 weeks; IQR 103–109 weeks), 877 (69%) adults from 710 households (71%) were assessed again; 441 adults (50%) had moved to and were living in East Village at follow-up. In the control group (436 (50%) adults), 205 (26%) adults had remained at their baseline address at follow-up, while 231 (23%) adults had moved elsewhere. Age, sex and ethnic group at baseline were similar for those followed-up and not followed-up, although those followed-up had higher socio-economic status (Supplementary Table 1).

Baseline characteristics of 877 adults from 710 households seen at follow-up are shown in [table 1](#), overall and by housing group. Overall, the East Village group were younger, more likely to be of black ethnicity, were less likely to have a degree qualification and less likely to be employed compared with controls. No baseline differences were observed in mental health and well-being between the East Village and control groups, but at baseline the East Village group reported poorer perceptions of their neighbourhood, that is, more crime and poorer quality at baseline; there was little overall difference in objective measures of the built environment. In the social housing group, the East Village and control groups were similar in age, sex and socio-economic characteristics, but the East Village group were more likely to be of black ethnicity. At baseline they also reported lower levels of anxiety and lower neighbourhood quality scores and had decreased access to public transport and walkability compared with the control group. Among the intermediate participants, the East Village group were younger, with more males and a higher

proportion from white ethnic groups compared with the control group; household composition and socioeconomic status were similar between East Village and control groups. At baseline, the East Village group had slightly higher anxiety levels and lower neighbourhood quality scores and higher public transport accessibility compared with the control group. In the market-rent group, East Village participants were younger than control participants; other baseline characteristics were similar in the two groups.

[Table 2](#) shows the change in exposure to the built environment and neighbourhood perceptions for the East Village group compared with the control group. Participants who were living in East Village at follow-up lived closer to their nearest park, had better access to public transport and lived in a more walkable area compared with their baseline area of residence. These differences were observed within each housing sector with no apparent differential effects across housing groups. There were also increases in the neighbourhood perception scores for safety (3.4, 95% CI 2.9 to 3.9) and quality (5.0, 95% CI 4.5 to 5.4) for the East Village group compared with controls, suggesting that there was no evidence that effects differed by housing group. Perceptions of safety and quality seemed similar across housing groups. Distributions of individual change from baseline to follow-up for built environment and neighbourhood perception outcomes for the East Village group, controls who had moved from their baseline address and controls who had remained at their baseline address have been published elsewhere.<sup>14</sup> In brief, there was considerable improved change in these outcomes for the East Village group compared with their baseline address after 2 years. Those who had moved elsewhere also showed improved change compared with control participants who did not move; however, these changes were substantially less than those in the East Village group.

Despite changes in both objective and subjective assessments of the built environment, moving to East Village was not associated with a change in mental health and well-being overall compared with the control group, and no differential effects were observed by housing tenure status ([table 3](#)). The inclusion of an interaction term for East Village/control group and housing tenure was not statistically significant. Sensitivity analyses comparing change in outcomes among East Village participants with (i) controls who stayed at their baseline address and (ii) controls who had moved elsewhere suggested no evidence that effect sizes for mental health differed (Supplementary Table 2). Limiting the models to those who were followed-up within 28 days of their target 2-year follow-up date gave broadly similar results (data not shown). Imputation analyses for the mental health and well-being outcomes gave similar results to the complete case analysis (Supplementary Table 3).

## DISCUSSION

Despite observing sizeable improvements in objective measures of the quality of the built environment (with increased access to parks, public transport and walkability) and perceptions of the neighbourhood associated with moving to East Village, there was no clear evidence of an effect on mental health and well-being outcomes at 2-year follow-up.

These null findings are consistent with a small number of longitudinal studies that have examined the effect of change in the built environment or urban regeneration on mental health and well-being. Although not an urban regeneration study per se, a large-scale experimental study carried out in five US cities, the Moving to Opportunity (MTO) Study, examined the long-term

**Table 1** Baseline sociodemographic characteristics, mental health and well-being, and neighbourhood perceptions: Control and East Village groups overall and by housing group

	All housing groups (n=877)			Social (n=344)			Intermediate (n=377)			Market rent (n=156)		
	Control N (%)	East Village n (%)	p-value	Control n (%)	East Village n (%)	p-value	Control n (%)	East Village n (%)	p-value	Control n (%)	East Village n (%)	p-value
<b>Age group</b>												
16–24	75 (17%)	104 (24%)	0.01	18 (15%)	47 (21%)	0.27	30 (15%)	38 (22%)	<0.001	27 (25%)	19 (40%)	0.07
25–34	185 (42%)	194 (44%)		32 (26%)	61 (28%)		100 (49%)	113 (65%)		53 (49%)	20 (43%)	
35–49	138 (32%)	123 (28%)		66 (53%)	95 (43%)		61 (30%)	22 (13%)		11 (10%)	6 (13%)	
50+	38 (9%)	20 (5%)		8 (6%)	17 (8%)		12 (6%)	1 (1%)		18 (17%)	2 (4%)	
<b>Sex: Female</b>	248 (57%)	247 (56%)	0.79	91 (73%)	158 (72%)	0.75	107 (53%)	70 (40%)	0.02	50 (46%)	19 (40%)	0.53
<b>Ethnic group</b>												
White	225 (52%)	212 (48%)	<0.001	25 (20%)	38 (17%)	<0.001	122 (60%)	139 (80%)	<0.001	78 (72%)	35 (74%)	0.42
Black	91 (21%)	56 (13%)		47 (38%)	31 (14%)		35 (17%)	18 (10%)		9 (8%)	7 (15%)	
Asian	81 (19%)	131 (30%)		40 (32%)	120 (55%)		32 (16%)	9 (5%)		9 (8%)	2 (4%)	
Other	39 (9%)	42 (10%)		12 (10%)	31 (14%)		14 (7%)	8 (5%)		13 (12%)	3 (6%)	
<b>Household composition</b>												
1 person	34 (8%)	30 (7%)	0.20	5 (4%)	14 (6%)	0.22	17 (8%)	9 (5%)	0.45	12 (11%)	7 (15%)	0.88
2 people	147 (34%)	127 (29%)		20 (16%)	33 (15%)		82 (40%)	76 (44%)		45 (41%)	18 (38%)	
3 people	97 (22%)	94 (21%)		16 (13%)	45 (20%)		52 (26%)	38 (22%)		29 (27%)	11 (23%)	
4 or more people	158 (36%)	190 (43%)		83 (67%)	128 (58%)		52 (26%)	51 (29%)		23 (21%)	11 (23%)	
<b>Living with partner</b>												
Yes	210 (48%)	186 (42%)	0.02	60 (48%)	84 (38%)	0.17	101 (50%)	82 (47%)	0.78	49 (45%)	20 (42%)	0.17
No	205 (47%)	215 (49%)		50 (40%)	103 (47%)		96 (47%)	88 (50%)		59 (54%)	24 (51%)	
Unknown	21 (5%)	40 (9%)		14 (11%)	33 (15%)		6 (3%)	4 (2%)		1 (1%)	3 (6%)	
<b>Living with children: Yes</b>	172 (39%)	203 (46%)	0.05	109 (88%)	178 (81%)	0.09	52 (26%)	21 (12%)	<0.001	11 (10%)	4 (9%)	0.76
<b>Education</b>												
Degree or equivalent/higher	287 (66%)	249 (56%)	0.01	34 (28%)	55 (25%)	0.60	166 (82%)	154 (88%)	0.18	87 (80%)	40 (84%)	0.39
Intermediate qualification	102 (24%)	137 (31%)		59 (48%)	118 (54%)		26 (13%)	15 (9%)		17 (16%)	4 (8%)	
Other/None	45 (10%)	55 (12%)		30 (24%)	47 (21%)		11 (5%)	5 (3%)		4 (4%)	3 (6%)	
<b>Employment status</b>												
Employed	347 (80%)	307 (70%)	0.004	67 (54%)	98 (45%)	0.18	183 (90%)	169 (97%)	0.02	97 (89%)	40 (84%)	0.51
Unemployed	22 (5%)	36 (8%)		12 (10%)	33 (15%)		4 (2%)	1 (1%)		6 (5%)	2 (4%)	
Economically inactive	67 (15%)	97 (22%)		45 (36%)	88 (40%)		16 (8%)	4 (2%)		6 (5%)	5 (11%)	
<b>MS-SEC</b>												
Higher managerial/professional	246 (57%)	179 (41%)	<0.001	24 (20%)	23 (11%)	0.12	146 (73%)	124 (72%)	0.01	76 (70%)	32 (68%)	0.53
Intermediate occupations	54 (12%)	69 (16%)		16 (13%)	27 (12%)		22 (11%)	34 (20%)		16 (15%)	8 (17%)	
Routine/manual occupations	44 (10%)	56 (13%)		26 (21%)	46 (21%)		13 (6%)	10 (6%)		5 (5%)	0 (0%)	
Unemployed/econ inactive	89 (21%)	133 (30%)		57 (46%)	121 (56%)		20 (10%)	5 (3%)		12 (11%)	7 (15%)	

Continued

Table 1 Continued

	All housing groups (n=877)				Social (n=344)		Intermediate (n=377)		Market rent (n=156)		
	Control N (%)	East Village n (%)	p-value	Control n (%)	East Village n (%)	p-value	Control n (%)	East Village n (%)	Control n (%)	East Village n (%)	p-value
Limiting longstanding illness	59 (14%)	58 (13%)	0.87	28 (23%)	49 (22%)	0.95	23 (11%)	6 (3%)	8 (7%)	3 (6%)	1.00
Built environment (mean (sd))*											
Distance to closest park	666 (41.0)	659 (39.7)	0.80	597 (33.9)	622 (36.0)	0.52	712 (44.5)	696 (39.5)	665 (41.5)	713 (56.7)	0.59
Public transport accessibility	4.6 (1.8)	4.6 (1.9)	0.92	4.5 (1.9)	4.1 (1.8)	0.03	4.5 (1.8)	5.1 (1.9)	4.8 (1.8)	5.2 (2.0)	0.27
Walkability	0.1 (2.5)	-0.1 (2.7)	0.32	0.0 (1.9)	-0.6 (2.1)	0.02	0.1 (2.7)	0.4 (2.7)	0.4 (2.8)	0.8 (4.6)	0.51
Neighbourhood perceptions (mean (sd))†											
Safety	2.5 (4.2)	1.6 (4.6)	0.002	0.9 (4.7)	0.3 (4.5)	0.25	3.2 (3.8)	2.7 (4.1)	3.2 (3.8)	3.7 (4.4)	0.47
Quality	4.5 (4.5)	2.6 (4.4)	<0.001	3.4 (4.5)	1.7 (4.5)	<0.001	4.7 (4.5)	3.6 (4.3)	5.1 (4.3)	3.4 (3.8)	0.02
Mental health and well-being (median, IQR)‡											
Depression	3.5 (1.2, 5.8)	3.5 (1.2, 5.8)	0.91	4.7 (2.3, 7.0)	4.7 (2.3, 7.0)	0.56	3.5 (1.2, 5.8)	3.5 (1.2, 4.7)	2.3 (1.2, 4.7)	2.3 (1.2, 3.5)	0.31
Anxiety	6.0 (4.0, 8.2)	6.0 (3.0, 8.0)	0.47	7.0 (4.0, 9.3)	5.0 (3.0, 8.0)	0.02	5.0 (3.0, 8.0)	6.0 (4.0, 9.0)	7.0 (4.0, 9.0)	5.0 (3.0, 8.0)	0.19
Life satisfaction	7.0 (7.0, 8.0)	7.0 (6.0, 8.0)	0.62	7.0 (5.0, 9.0)	7.0 (6.0, 9.0)	0.29	7.0 (7.0, 8.0)	7.0 (6.0, 8.0)	7.0 (7.0, 8.0)	7.0 (7.0, 8.0)	0.45
Feeling life is worthwhile	8.0 (7.0, 9.0)	8.0 (7.0, 9.0)	0.23	8.0 (6.0, 9.0)	8.0 (7.0, 10.0)	0.08	8.0 (7.0, 9.0)	8.0 (7.0, 9.0)	8.0 (7.0, 8.0)	8.0 (7.0, 9.0)	0.78
Feeling happy yesterday	8.0 (6.0, 9.0)	8.0 (6.0, 9.0)	0.46	8.0 (6.0, 9.0)	8.0 (6.0, 9.0)	0.73	8.0 (7.0, 9.0)	7.5 (6.0, 8.0)	7.0 (6.0, 8.0)	7.0 (6.0, 9.0)	0.60

\*Built environment variables were available for those living in the Greater London area at baseline: 406 in the Control group and 414 in the East Village group. Distance to closest park from choice of local, district and metropolitan parks. PTAL is a Transport for London (TfL) score assessing the availability of public transport options where a high score indicates good public transport links. Walkability is the sum of three z-transformed variables—land use mix, residential density and street connectivity.

†Neighbourhood perception scores were available for 436 and 441 for Control and East Village participants respectively. The safety scale is scored -10 to +10, where higher scores indicate less perceived crime. The Quality scale is scored -12 to +12, where higher scores indicate higher perceived quality.

‡Mental health outcomes were available for 416, 424 for depression; 431, 435 for anxiety; and 432, 441 life satisfaction, life is worthwhile, feeling happy yesterday for control and East Village participants respectively. Depression and anxiety are scored 0-21 where higher scores indicate higher depression or anxiety. Life satisfaction, feeling life is worthwhile and feeling happy yesterday are scores 1-10 where higher scores indicate greater levels.

**Table 2** Change in the built environment characteristics and neighbourhood perception scores in East Village group compared with change in control group, overall and by housing group

	All housing groups		Social housing group		Intermediate housing group		Market-rent housing group		Interaction term
	Difference (95% CI)	P value	Difference (95% CI)	P value	Difference (95% CI)	P value	Difference (95% CI)	P value	
<b>Built environment characteristics (n=790) *</b>									
Distance to closest park	-528 (-575, -482)	<0.001	-581 (-649, -512)	<0.001	-439 (-513, -366)	<0.001	-612 (-737, -487)	<0.001	0.01
TfL PTAL score	1.6 (1.3, 1.9)	<0.001	1.4 (0.9, 1.8)	<0.001	2.3 (1.8, 2.8)	<0.001	0.6 (-0.2, 1.4)	0.13	<0.001
Walkability	2.1 (1.9, 2.4)	<0.001	1.8 (1.4, 2.2)	<0.001	2.5 (2.1, 3.0)	<0.001	2.1 (1.4, 2.9)	<0.001	0.09
<b>Neighbourhood perception scales (n=877)†</b>									
Safety	3.4 (2.9, 3.9)	<0.001	3.4 (2.7, 4.2)	<0.001	3.9 (3.0, 4.7)	<0.001	2.2 (0.9, 3.4)	<0.001	0.10
Quality	5.0 (4.5, 5.4)	<0.001	5.3 (4.6, 6.0)	<0.001	4.5 (3.7, 5.3)	<0.001	5.0 (3.8, 6.2)	<0.001	0.33

Estimates of the difference between East Village and control groups are from multilevel models adjusting for sex, age group and ethnicity with household as a random effect.

\*Built environment variables were available for 790 living in the Greater London area at baseline and at follow-up. Distance to closest park from choice of local, district and metropolitan parks. PTAL is a Transport for London (TfL) score assessing the availability of public transport options, where a high score indicates good public transport links. Walkability is the sum of three z-transformed variables—land-use mix, residential density and street connectivity.

†Neighbourhood perception scores are scored -10 to +10 for safety and -12 to +12 for quality; higher scores indicate less perceived crime and higher perceived quality.

effect of moving from high to low poverty neighbourhoods on the physical and mental health of 4606 minority low-income families.<sup>16 17</sup> While improvements in living conditions among the intervention group were demonstrated over a 10-year to 15-year period, there was little difference in adult mental health-related outcomes and economic self-sufficiency between groups, although a small improvement in subjective well-being associated with moving to less deprived neighbourhoods was observed.<sup>16 17</sup> An urban regeneration study in four neighbourhoods (including refurbishment of public spaces and community buildings) in Barcelona, Spain, showed a modest reduction in mental health disorders after 5 years, compared with a control population living outside the intervention areas.<sup>26</sup> Another large-scale urban regeneration scheme in 40 districts in the Netherlands (targeting levels of unemployment, education, as well as housing conditions, including building new homes and housing refurbishment) showed no effect of the intervention on mental health outcomes at 3 years.<sup>27</sup> From a UK perspective, a large long-term housing improvement programme (including neighbourhood demolition, new and refurbished homes, with improved amenities and services) in Glasgow, Scotland, showed a small positive effect on mental health scores after 2 years.<sup>28</sup> Additionally, mental health scores in the most deprived areas which received higher levels of investment improved more after 5 years compared with lower investment areas. This study suggested that urban renewal programmes might offer a strategy to address health inequalities, though effects are small.<sup>29</sup> In addition, findings showed that the scheme may have actually increased fear of crime, as relocation

may have disturbed established social networks.<sup>30</sup> Other UK studies which have examined the effect of urban regeneration programmes including change in the built environment have also shown little effect on mental health and well-being outcomes, although change in the built environment has not always been well defined.<sup>31</sup> Geographically, the closest study to the ENABLE London study also used a natural experiment to examine the effect of London Olympic regeneration among 2254 children attending secondary schools across the London Borough of Newham, compared with pupils attending schools in other East London boroughs. They found no effect of urban regeneration on self-reported physical activity, mental health and well-being outcomes after 18 months, and repeated cross-sectional surveys among 995 parents suggested that levels of anxiety and depressive symptoms might have increased rather than decreased in Newham, compared with control areas.<sup>32</sup>

Although there is considerable enthusiasm for the potential of the built environment to promote mental health and well-being, to date the evidence appears to be either null or modest at best. The proposed pathways through which the built environment may affect mental health and well-being are complex with direct and indirect pathways,<sup>33</sup> and there is limited high-quality evidence available to establish causality.<sup>12</sup> It has been suggested that the null or biased findings reported may be due to low follow-up rates, small sample sizes and the inclusion of control groups who chose not to move who may have different underlying health behaviours.<sup>12 29 31</sup> Heterogeneous study designs and methods used, particularly in characterising the built environment and

**Table 3** Change in mental health and well-being outcomes and neighbourhood perception scores in East Village group compared with change in control group, overall and by housing group

	N	All housing groups		Social housing group		Intermediate housing group		Market-rent housing group		Interaction term
		Difference (95% CI)	P value	Difference (95% CI)	P value	Difference (95% CI)	P value	Difference (95% CI)	P value	
Depression	814	-0.2 (-0.6, 0.2)	0.32	-0.3 (-0.9, 0.3)	0.37	-0.2 (-0.9, 0.5)	0.56	0.0 (-1.0, 1.0)	0.96	0.92
Anxiety	854	-0.1 (-0.6, 0.4)	0.64	-0.4 (-1.1, 0.3)	0.23	0.4 (-0.4, 1.1)	0.36	-0.3 (-1.5, 0.8)	0.59	0.31
Life satisfaction	871	0.2 (-0.1, 0.4)	0.15	0.3 (0.0, 0.6)	0.08	0.0 (-0.4, 0.4)	0.96	0.1 (-0.4, 0.7)	0.64	0.51
Feeling life is worthwhile	868	0.1 (-0.1, 0.3)	0.46	0.0 (-0.3, 0.4)	0.85	0.2 (-0.2, 0.5)	0.39	0.1 (-0.5, 0.6)	0.85	0.87
Feeling happy yesterday	869	0.2 (-0.1, 0.5)	0.14	0.3 (-0.1, 0.7)	0.18	0.2 (-0.3, 0.6)	0.45	0.1 (-0.6, 0.7)	0.79	0.88

Estimates of the difference between East Village and control groups are from multilevel models adjusting for sex, age group and ethnicity with household as a random effect. The model for 'all housing groups' additionally adjusts for housing group. The estimates for individual housing group were obtained from a model with an interaction term for East Village group and housing group.

quantifying mental health or well-being outcomes, have also hampered the pooling of findings across studies.<sup>12</sup> Additionally, some studies include long periods of urban regeneration,<sup>16 17</sup> which makes it difficult to discern the effects of a specific change in the built environment from changes occurring in the underlying population over time.

The ENABLE London Study sought to address these limitations. This study used a unique opportunity to evaluate a natural experiment, making use of the rapid repurposing of East Village, a well-characterised built environment, where good participation and follow-up rates were achieved (near 70%) and recruitment of a control population who were also seeking to move to East Village. This limited the role of bias in any comparisons made.<sup>14</sup> In addition, little differences were observed in the mental health and well-being outcomes and neighbourhood perception scores reported at baseline between those followed-up and those not followed-up, suggesting that those included in the analyses were not select. Examining individual change within the same individuals over time also offered statistical efficiencies as individuals act as their own controls and confounders remain constant. Despite this, the findings are largely in line with previous work and provide no evidence for the effect of the built environment on mental health and well-being.

It is important to acknowledge some of the limitations of the ENABLE Study. Mental health and well-being outcomes were secondary to the main hypothesis of the study, and the wide CIs associated with effects on mental health and well-being suggest that the study lacked statistical power, more so when considering effects across housing tenured subgroups. However, the lack of formal evidence of a difference across housing tenured groups allays concerns that such interventions might widen social inequalities. The staggered recruitment, where those in social housing were moved in before other housing types, before the East Village development was fully complete, may have dampened exposure effects and not allowed sufficient time for social networks that might encourage positive mental health and well-being to become established.<sup>34</sup> While no appreciable change in the primary outcome of the study (physical activity) was observed,<sup>14</sup> which could have plausibly impacted mental health and well-being, it remains possible that a longer term follow-up may have demonstrated significant effects. However, this seems unlikely given the weak evidence from other urban regeneration studies with longer durations of follow-up.<sup>16 17 26 27</sup> While further follow-up of the cohort might be informative in ascertaining longer term effects, this might be adversely affected by the continued development of East Village; high-rise accommodation blocks (with 30+ storey accommodation being built among the existing 10–12 storey accommodation), reductions in green space<sup>14</sup> and the high turnover of residents with rental tenancies could weaken social bonds and cohesion contributing to worse mental health and well-being.<sup>35</sup> Unfortunately, the high mobility of residents also means that we have lost contact with many who took part in the study, making further follow-up of sufficient numbers infeasible. This high level of mobility may itself partly explain our findings: residents dissatisfied with their apartment or neighbourhood are more likely to relocate, and higher mobility weakens social ties, which is protective of mental health.<sup>36</sup>

Despite the growing need for more housing, particularly in major cities, opportunities to examine the potential health impact of urban development are limited. It is widely accepted that urban renewal programmes should be designed to have positive impacts on its residents, as well as reducing health inequalities through tackling the social and environmental determinants of health.<sup>37 38</sup> However, it is challenging to create high-density

urban environments with appropriate local facilities to promote positive health behaviours, while also protecting residents from the potentially adverse effects of high-density housing.<sup>39</sup> There is little understanding of what is the optimum density and the community facilities and services that encourage social contact to improve mental health and well-being, especially among the more disadvantaged, which might mask the potential benefits of better housing.<sup>40</sup> This study adds high-quality evidence to the debate, showing that the East Village design has had little impact on the mental health and well-being of residents from different socioeconomic groups after 2 years. These findings suggest that more personal (ie, catered to the individual) and/or community-wide (eg, place-making activities that foster community engagement) intervention strategies may be needed.

### What is already known on this subject

- ▶ Few urban regeneration studies have examined the effect of change in the built environment on mental health and well-being; even fewer have longitudinal designs.
- ▶ These studies show no evidence of an effect of urban regeneration on mental health and well-being, but studies are heterogeneous; they do not fully quantify characteristics of the built environment and are at high risk of bias (largely due to poor follow-up).
- ▶ More robust study designs, such as natural experiments, are needed to examine the association of urban regeneration on mental health and well-being.

### What this study adds

- ▶ The repurposed East Village, formerly the London 2012 Olympic and Paralympic Athletes' Village, offered a unique opportunity for a natural experiment.
- ▶ Despite demonstrating marked improvements in objective markers of the built environment and neighbourhood perceptions associated with moving to East Village, there was no clear evidence of improvements in mental health (anxiety and depression) and subjective well-being (life satisfaction, feelings of worthiness and happiness) at 2-year follow-up.
- ▶ These findings suggest that the built environment alone is insufficient to affect mental health and well-being and that other interventions are also needed.

### Author affiliations

<sup>1</sup>Population Health Research Institute, St George's, University of London, London, UK

<sup>2</sup>Department of Public Health, Environments & Society, London School of Hygiene and Tropical Medicine, London, UK

<sup>3</sup>National Institute for Health Research Bristol Biomedical Research Centre, University Hospitals Bristol NHS Foundation Trust and University of Bristol, Bristol, UK

<sup>4</sup>Centre for Exercise, Nutrition and Health Sciences, University of Bristol, Bristol, UK

<sup>5</sup>MRC/SCO Social and Public Health Sciences Unit, University of Glasgow, Glasgow, UK

<sup>6</sup>NHMRC Centre of Research Excellence in Healthy Liveable Communities, RMIT University, Melbourne, Victoria, Australia

**Acknowledgements** This research is being supported by project grants from the UK National Prevention Research Initiative (MR/J000345/1) and the UK National Institute for Health Research (NIHR; 12/211/69). Diabetes and obesity prevention research at St George's, University of London is supported by the NIHR Collaboration for Leadership in Applied Health Research and Care, South London. BR was supported by a PhD studentship from St George's, University of London. CMN is supported by the Wellcome Trust Institutional Strategic Support Fund (204809/Z/16/Z). ARC and ASP

are supported by the NIHR Biomedical Research Centre at University Hospitals Bristol National Health Service Foundation Trust and the University of Bristol. AE is funded by the Medical Research Council as part of the Neighbourhoods and Communities Programme (MC\_UU\_12017–10). BG-C is supported by a National Health and Medical Research Council Principal Research Fellowship (1107672). The views expressed in this publication are those of the author(s) and not necessarily those of the UK National Health Service, the NIHR, or the Department of Health. The authors thank the East Thames Group, Triathlon Homes, and Get Living London who assisted in recruiting participants into the ENABLE London Study. The ENABLE London Study was advised by a Steering Committee chaired by Hazel Inskip (University of Southampton), with David Ogilvie (University of Cambridge) and Andy Jones (University of East Anglia) as academic advisors, and Kate Worley (formerly East Thames Group Assistant Director for Strategic Housing) as the lay or stakeholder member. The authors are grateful to the members of the ENABLE London Study team (particularly Aine Hogan, Katrin Peuker and Cathy McKay) and to participating households, without whom this study would not be possible.

**Contributors** CGO, PHW, BG-C, DGC, ARR, DL, SC, ARC, ASP and AE designed the study and raised funding. BR, ARR and CGO enrolled participants. BR, CC, ARR and CGO collected data for the study; BR, ESL, CMN, CC, DP, ARR and CGO managed the data; and BR and ESL analysed the data. BR wrote the first draft of the paper to which all authors contributed. CGO is responsible for data integrity and affirms that the manuscript is an honest, accurate and transparent account of the study being reported; that no important aspects of the study have been omitted and that any discrepancies from the study as originally planned (and, if relevant, registered) have been explained.

**Competing interests** None declared.

**Patient consent for publication** Not required.

**Data sharing statement** Further details of the ENABLE London Study are available from the study website. Proposals for collaborative projects are welcome. For general data sharing inquiries, contact Professor Christopher Owen.

**Provenance and peer review** Not commissioned; externally peer reviewed.

**Open access** This is an open access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited, appropriate credit is given, any changes made indicated, and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/4.0/>.

#### ORCID iDs

Bina Ram <http://orcid.org/0000-0003-0023-1573>  
 Elizabeth S Limb <http://orcid.org/0000-0003-0830-7376>  
 Aparna Shankar <http://orcid.org/0000-0002-7948-8189>  
 Claire M Nightingale <http://orcid.org/0000-0003-2408-757X>  
 Alicja R Rudnicka <http://orcid.org/0000-0003-0369-8574>  
 Steven Cummins <http://orcid.org/0000-0002-3957-4357>  
 Ashley R Cooper <http://orcid.org/0000-0001-8644-3870>  
 Anne Ellaway <http://orcid.org/0000-0002-2117-4451>  
 Billie Giles-Corti <http://orcid.org/0000-0003-0102-0225>  
 Peter H Whincup <http://orcid.org/0000-0002-5589-4107>  
 Derek G Cook <http://orcid.org/0000-0002-9723-5759>  
 Christopher G Owen <http://orcid.org/0000-0003-1135-5977>

#### REFERENCES

- World Health Organization. *Depression and other common mental health disorders: Global Health Estimates*. Geneva: World Health Organisation, 2017.
- World Health Organization. *Mental health fact sheet*. WHO Regional Office for Europe, 2019. Available [http://www.euro.who.int/\\_\\_data/assets/pdf\\_file/0004/404851/MNH\\_FactSheet\\_ENG.pdf?ua=1](http://www.euro.who.int/__data/assets/pdf_file/0004/404851/MNH_FactSheet_ENG.pdf?ua=1)
- Ritchie H, Roser M. *Mental health - our world in data*. University of Oxford, Global Change Data Lab, 2018. Available <https://ourworldindata.org/mental-health#depression>
- McManus S, Bebbington P, Jenkins R, et al. *Mental health and wellbeing in England: adult psychiatry morbidity survey 2014*. NHS Digital, 2016. Available <http://content.digital.nhs.uk/catalogue/PUB21748/apms-2014-full-rpt.pdf>
- Office for National Statistics. *Measuring national well-being: life in the UK*. ONS, 2017. Available <https://www.ons.gov.uk/releases/measuringnationalwellbeinglifeintheukapr2017>
- United Nations. *68% of the world population projected to live in urban areas by 2050*. United Nations, Department of Economic and Social Affairs: New York, 2018. Available <https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html>
- World Health Organization. *How to make a healthy city*. WHO, 2019. Available <https://cities-spotlight.who.int/>
- Adli M, Berger M, Brakemeier E, et al. Neurourbanism - A joint methodological approach between urban planning and neurosciences. *Die Psychiatrie* 2016;13:70–8.
- Gruebner O, Rapp MA, Adli M, et al. Cities and mental health. *Dtsch Arztebl Int* 2017;114:121–7.
- Evans GW. The built environment and mental health. *J Urban Health* 2003;80:536–55.
- O'Campo P, Salmon C, Burke J. Neighbourhoods and mental well-being: what are the pathways? *Health Place* 2009;15:56–68.
- Moore THM, Kesten JM, Lopez-Lopez JA, et al. The effects of changes to the built environment on the mental health and well-being of adults: systematic review. *Health Place* 2018;53:237–57.
- Diez Roux AV, Mair C. Neighborhoods and health. *Ann N Y Acad Sci* 2010;1186:125–45.
- Nightingale CM, Limb ES, Ram B, et al. The effect of moving to east village, the former London 2012 Olympic and Paralympic Games Athletes' Village, on physical activity and adiposity (ENABLE London): a cohort study. *Lancet Public Health* 2019;4:e421–30.
- Egan M, Lawson L, Kearns A, et al. Neighbourhood demolition, relocation and health. A qualitative longitudinal study of housing-led urban regeneration in Glasgow, UK. *Health Place* 2015;33:101–8.
- Ludwig J, Duncan GJ, Genetian LA, et al. Long-term neighborhood effects on low-income families: evidence from moving to opportunity. *Am Econ Rev* 2013;103:226–31.
- Ludwig J, Duncan GJ, Genetian LA, et al. Neighborhood effects on the long-term well-being of low-income adults. *Science* 2012;337:1505–10.
- Ram B, Nightingale C, Hudda MT, et al. Cohort profile: examining neighbourhood activities in built living environments in London: the ENABLE London - Olympic Park cohort. *BMJ Open* 2016;6:e012643.
- GIGL. Greenspace Information for Greater London CIC. 2019. Available <https://www.gigl.org.uk/>
- Transport for London (TfL). Public transport accessibility levels. 2016. Available <https://www.gigl.org.uk/>
- Ram B, Shankar A, Nightingale CM, et al. Comparisons of depression, anxiety, well-being, and perceptions of the built environment amongst adults seeking social, intermediate and market-rent accommodation in the former London Olympic Athletes' Village. *Health Place* 2017;48:31–9.
- Zigmond AS, Snaith RP. The hospital anxiety and depression scale. *Acta Psychiatr Scand* 1983;67:361–70.
- Bjelland I, Dahl AA, Haug TT, et al. The validity of the hospital anxiety and depression scale - an updated literature review. *J Psychosom Res* 2002;52:69–77.
- Herrmann C. International experiences with the hospital anxiety and depression scale - a review of validation data and clinical results. *J Psychosom Res* 1997;42:17–41.
- Office for National Statistics. *Measuring national well-being*. ONS, 2015. Available <http://www.ons.gov.uk/peoplepopulationandcommunity/wellbeing/bulletins/measuringnationalwellbeing/2015-09-23#the-measuring-national-well-being-programme>
- Mehdipanah R, Rodriguez-Sanz M, Malmusi D, et al. The effects of an urban renewal project on health and health inequalities: a quasi-experimental study in Barcelona. *J Epidemiol Community Health* 2014;68:811–17.
- Jongeneel-Grimen B, Droomers M, Kramer D, et al. Impact of a Dutch urban regeneration programme on mental health trends: a quasi-experimental study. *J Epidemiol Community Health* 2016;70:967–73.
- Egan M, Katikireddi SV, Kearns A, et al. Health effects of neighborhood demolition and housing improvement: a prospective controlled study of 2 natural experiments in urban renewal. *Am J Public Health* 2013;103:E47–E53.
- Egan M, Kearns A, Katikireddi SV, et al. Proportionate universalism in practice? A quasi-experimental study (GoWell) of a UK neighbourhood renewal programme's impact on health inequalities. *Soc Sci Med* 2016;152:41–9.
- Lorenc T, Petticrew M, Whitehead M, et al. Fear of crime and the environment: systematic review of UK qualitative evidence. *BMC Public Health* 2013;13:496.
- Huxley P, Evans S, Leese M, et al. Urban regeneration and mental health. *Soc Psych Psych Epid* 2004;39:280–5.
- Cummins S, Clark C, Lewis D, et al. *The effects of the London 2012 Olympics and related urban regeneration on physical and mental health: the ORIeL mixed-methods evaluation of a natural experiment*. Southampton (UK): Public Health Research, 2018.
- Lorenc T, Clayton S, Neary D, et al. Crime, fear of crime, environment, and mental health and wellbeing: mapping review of theories and causal pathways. *Health Place* 2012;18:757–65.
- McElroy E, McIntyre J, Bentall R, et al. Mental health, deprivation, and the neighborhood social environment: a network analysis. *Clin Psychol Sci* 2019;7:719–34.
- Laurence J, Heath A. Predictors of community cohesion: multi-level modelling of the 2005 citizenship survey. 2008. Available <https://pdfs.semanticscholar.org/7104/f402521b495358cb063f36202666b9d41243.pdf>
- Giles-Corti BRK, Foster S. Increasing density in Australia: maximising the health benefits and minimising harm. 2012. Available <https://www.heartfoundation.org.au/images/uploads/publications/Increasing-density-in-Australia-Evidence-Review-2012-trevor.pdf>
- Kearns A, Tannahill C, Bond L. Regeneration and health: conceptualising the connections. *J Urban Regener Renewal* 2009;3:56–76.
- World Health Organization. Closing the gap in a generation: health and equity through action on the social determinants of health. Final report of the commission on social determinants of health. 2008. Available [http://apps.who.int/iris/bitstream/handle/10665/43943/9789241563703\\_eng.pdf?sequence=1](http://apps.who.int/iris/bitstream/handle/10665/43943/9789241563703_eng.pdf?sequence=1)
- Kent J, Thompson S. Connecting and strengthening communities in places for health and well-being. *Australian Planner* 2014;51:260–71.
- Giles-Corti B, Vernez-Moudon A, Reis R, et al. City planning and population health: a global challenge. *Lancet* 2016;388:2912–24.