The effects of changes to the built environment on the mental health and well-being of adults: Systematic review


A R T I C L E   I N F O

Keywords:
Systematic review
Urban environment
Mental health
Well-being
Meta-analysis

A B S T R A C T

There is increasing interest in the influence of place on health, and the need to distinguish between environmental and individual level factors. For environmental-level factors, current evidence tends to show associations through cross-sectional and uncontrolled longitudinal analyses rather than through more robust study designs that can provide stronger causal evidence. We restricted this systematic review to randomised (or cluster) randomised controlled trials and controlled before-and-after studies of changes to the built environment. Date of search was December 2016. We identified 14 studies. No evidence was found of an effect on mental health from ‘urban regeneration’ and ‘improving green infrastructure’ studies. Beneficial effects on quality-of-life outcomes from ‘improving green infrastructure’ were found in two studies. One ‘improving green infrastructure’ study reported an improvement in social isolation. Risk-of-bias assessment indicated robust data from only four studies. Overall, evidence for the impact of built environment interventions on mental health and quality-of-life is weak. Future research requires more robust study designs and interdisciplinary research involving public health, planning and urban design experts.

1. Background

Mental health and well-being are important public health issues. In 2010, mental health disorders accounted for 56.7% of 258 million global disability-adjusted life years (DALYs) (Whiteford et al., 2015). In the United Kingdom (UK) mental health problems are the greatest cause of disability (Mental Health Taskforce, 2016) and, although trends in self-reported personal well-being are improving, mental health continues to deteriorate (Office for National Statistics, 2017a). Promoting health and well-being is a World Health Organization (WHO) Sustainable Development Goal for 2030 (United Nations, 2015) and WHO’s Comprehensive Mental Health Action Plan calls for a “multi-sectorial approach” to protect mental health and prevent mental health problems (World Health Organization, 2013).

There is increasing interest in the influence of place on health, and the need to distinguish between contributions of “contextual” (environmental level) and “compositional” (individual level) factors to area level health differences has been argued (Macintyre et al., 2002). There is increasing emphasis on the importance of environment on health and well-being (Scottish Government, 2008). Several systematic reviews highlight associations between environment and mental health and well-being (Won et al., 2016; Mair et al., 2008; Paczkowski and Galea, 2010; van den Berg et al., 2015; Lee and Maheswaran, 2011; Lavin et al., 2006; Gong et al., 2016; Croucher et al., 2007). However, evidence varies in quality and has tended to show associations through cross-sectional and uncontrolled longitudinal analyses rather than establishing causal effects through the use of randomized controlled trials (Barton et al., 2010; Bond et al., 2012; Ellaway et al., 2005; Guite et al., 2006; Horowitz et al., 2005; Stafford et al., 2007; White et al., 2013; Whiteley and Prince, 2005; Wu et al., 2015). Cross-sectional analyses have the limitation that there is ambiguous temporal precedence (i.e. it is unclear which variable is the cause and which is the effect), and longitudinal studies without a control group do not allow the possibility to distinguish between effects of the intervention from effects due to events that occur concurrently with the intervention, naturally occurring changes.
over time, or regression to the mean if the intervention group has been chosen due to extreme values (i.e. poor baseline mental health). Quasi-experimental studies, such as controlled before-after studies, if well-designed and performed, can reduce the risk of some of these barriers to interpretation. There is often no control for confounders such as healthier people choosing to live in neighbourhoods that support their mental health. Understanding these associations is impeded by: use of different measures of mental health, well-being and environmental domains; presence of mediators and moderators; and interactions between physical and mental health and well-being outcomes (Lachowycz and Jones, 2011).

Studies have indicated the following: neighbourhood aesthetic quality is positively associated with higher mental well-being (Bond et al., 2012); quality and accessibility of local environments in terms of availability of public transport, access to seating, attractiveness of the neighbourhood, and access to green space are key factors in improving use of the local neighbourhood by older adults (Stathis et al., 2012), and; risk of injury from traffic and disrepair of the built environment in low-income areas may adversely affect mental health (Lavin et al., 2006; Croucher et al., 2007; Ellaway et al., 2005; Horowitz et al., 2005; Stafford et al., 2007; Whitley and Prince, 2005).

Objective measures of urban environments (including neighbourhood quality, quantity of green space and land-use mix) have been associated with psychological distress (Gong et al., 2016). Similarly, objective measures of greenspace in living or home environments have been positively associated with perceived mental health (van den Berg et al., 2015; White et al., 2013) and negatively associated with depression and anxiety symptoms (Wu et al., 2015). However, Lee and Maheswaran (2011) concluded there is weak evidence for associations between mental health and well-being and urban green space, highlighting weak study designs in the literature.

Examining effects of modifications to the environment on mental health and well-being is complex and limited by methodological challenges associated with quasi-experimental evaluation. For instance, it is often challenging to define exposure to population level interventions and to identify an unexposed group (Egan et al., 2003; Ogilvie et al., 2010; Humphreys et al., 2016).

Most research and guidance to date has focused on relationships between the built environment and physical health rather than mental health and well-being (Egan et al., 2003; Bunn et al., 2003; Burns et al., 2014; Cerda et al., 2013; NICE, 2008; Tully Mark et al., 2013; World Health Organization, 2006). A systematic review of intervention studies examining effects of changes to the built environment on the health of children and young people found some evidence of potential benefits to physical activity but was unable to find any mental health and well-being outcomes in the literature (Audrey and Batista-Ferrer, 2015).

Responses to changes to the built environment to support health are likely to vary across the life-course (Villanueva et al., 2013). Worldwide, populations are ageing (World Health Organization, 2018) and in the UK specifically, the proportion of the population over 65 years is increasing (Office for National Statistics, 2017b) hence it is important to consider how changes to the built environment influence the mental health and well-being of adults and older adults. Furthermore, given exposure to green space is associated with fewer mental health disorders in older adults, it has been suggested planners should consider ways to encourage this group to use green space to support healthy ageing (Wu et al., 2015).

We found no systematic review evidence for intervention studies investigating effects of changes to the built environment on mental health and well-being in adults and older adults. This evidence is needed to inform recommendations to support policy decision making. The aim of this systematic review is to assess the evidence of changes to the built environment on mental health, well-being, quality of life, social inclusion and fear of crime in adults living in urban environments in high income countries.

2. Methods

A protocol with details of our planned research methods is registered with PROSPERO (Moore et al., 2015) and we reported the review according to PRISMA guidelines (Moher et al., 2009).

2.1. Search strategy

We searched using subject and text word terms for built environment (e.g. urban, built etc), intervention types (e.g. road safety, traffic calming, environment design, urban renewal etc) and terms describing mental health and well-being (e.g. wellness, quality of life, anxiety, stress etc). We focussed on adults and older adults as a recent review summarising effects of changes to the built environment on children and young people had been completed (Audrey and Batista-Ferrer, 2015). We restricted our search to studies published in English and excluded letters, editorials, and conference proceedings.

We searched 13 electronic bibliographic databases MEDLINE, PreMEDLINE, Embase and PsycINFO on OVID; Cochrane CENTRAL on The Cochrane Library; Core Collection on Web of Science; Database of Promoting Health Effectiveness Reviews (DOPHER); Trials Register of Promoting Health Interventions (TroPHI); Transport Research International Documentation (TRID) from US National Academies of Sciences, Engineering and Medicine; Health Evidence from McMaster University Canada; GreenFILE on EBSCO; Health Management Information Consortium (HMIC); GeoBASE on Elsevier and Planex. All databases were searched from inception to December 2016. We searched for grey literature and additional reports of research using Google, WHO trials registry, Clinical trials.gov, ISRCTN registry, OpenGrey, NHS Evidence, plus websites of 33 associations, charities, cities etc. (See Supplementary material for details of search terms used).

2.2. Inclusion criteria

We restricted study selection to randomized controlled trials (RCTs), cluster RCTs, controlled before-and-after studies, interrupted time series and regression discontinuity studies assessing the effects of any physical change to the built environment on adult or older adult mental health and well-being, quality of life, social inclusion or isolation, social capital, isolation or fear of crime.

We excluded studies in rural environments or low- or middle-income countries. It is expected that context specific factors are likely to influence the relationship between the built environment and mental health and well-being in these settings which would make drawing comparisons to high-income countries difficult. This approach is in line with previous research (Won et al., 2016; Lee and Maheswaran, 2011). Studies reporting introduction or upgrading of street lighting or closed circuit or surveillance cameras (CCTV) were excluded as these had recently been reviewed comprehensively (Lorenc, 2014). We excluded studies where changes were applied to environments not accessible to everyone or inside buildings (e.g. private grounds, schools, hospitals) as our interest was in the public realm. Studies where the main or sole intervention was either relocation from one area to another or improvement or refurbishment to the housing stock were also excluded.

2.3. Study selection, data extraction and analysis

We screened titles and abstracts and eligibility of full-text reports independently and in duplicate (TM, SI, JK, SA, SG). Data were extracted by one author and recorded on a predefined and piloted data extraction form and a second author checked extracted data (TM, JK, SI, AM, JLL). Extraction of numerical results and risk of bias assessments for each study were done by two reviewers independently (TM, SI, JK, AM, JLL). Any discrepancies in screening or data extraction were discussed until consensus was reached, with recourse to a third reviewer if required.
3.1. Study selection

Participant characteristics (sample size, age, ethnicity, and socioeconomic status) and outcome (type, measure, time point, effects) were extracted. We used the revised Cochrane risk-of-bias tool for randomized trials (Robins-I Tool, 2016) to assess the risk of bias in extracted results (Robins-I Tool, 2016). Robins-I assesses risk of bias by considering the non-randomized study as an attempt to emulate a hypothetical RCT, designed without features putting it at risk of bias, for the same intervention, conducted on the same participant group – the target trial (Sterne et al., 2016; Higgins et al., 2011). The outcome of interest was the effect of assignment to intervention on mental health.

3.2. Summary of included studies

Eight studies were from the UK, (Ward Thompson et al., 2014, 2013; Phillips et al., 2014a; Huxley and Rogers, 2004; Stansfeld et al., 2009; Curl et al., 2015; Egan et al., 2016; Ogilvie et al., 2016) three from the USA, (Kondo et al., 2015; Branas et al., 2011; Sandas, 2015) and one each from Spain, (Mehdipanah et al., 2014) the Netherlands (Jongeneel-Grimen et al., 2016) and Norway (Skjoelved, 2001). We categorised the studies based on the focus of the intervention or programme of interventions (Fig. 2) as ‘transport infrastructure modifications’ which included measures to improve walking and cycling, ‘improving green infrastructure’, and, ‘urban regeneration’ defined as community interventions with changes to the built environment or regenerating large areas of deprived areas in cities (e.g. housing demolition and improvement and new community buildings).

3.2.1. Transport infrastructure modifications

Two UK studies investigated the effects of a major change to road infrastructure on people aged 16 to over 65; ‘Noise reduction’ assessed the effects of a new road bypass in North Wales (Stansfeld et al., 2009) and the ‘Commuting and Health in Cambridge Study’ (CHCS) evaluated a purpose-built guided busway (segregated bus track) with an accompanying cycle and walking path linking towns and villages in Cambridgeshire (Ogilvie et al., 2016). One controlled before-and-after study, ‘DIY streets’, involved redesigning streets to look more attractive and safer such as buildouts to slow down traffic, planters, benches and lights and included analysis of the effect on older adults (Curl et al., 2015).

3.2.2. Improving green infrastructure

Six controlled before-and-after studies described interventions in which more greenery was brought into neighbourhoods through trees, parks and lawns etc. Two interventions, ‘Green storm water Philadelphia’ (GSW Philadelphia) and ‘Green storm water Portland’ (GSW Portland) changed management of storm water runoff using natural planting rather than concreted storm water drains (Kondo et al., 2015; Sandas, 2015). These studies did not describe participant age in detail. The ‘Woods in and around town (WIAT)’ intervention tried to improve perceptions of urban woodlands through local community projects and physical changes (Ward Thompson et al., 2013). Three interventions (‘Greening Vacant Lots’, ‘Street-parks’ and ‘DIY streets’) introduced new mini-parks or green areas in residential streets (Curl et al., 2015; Branas et al., 2011; Skjoelved, 2001). Mean ages for these three studies was 36–40 years.

3.2.3. Urban regeneration

Six studies investigated multifaceted large-scale interventions aimed at increasing physical activity and mental well-being either through community interventions with changes to the built environment or regenerating large areas of deprived areas in cities. Five of were controlled before-and-after studies (‘Wythenshawe regeneration’, ‘GoWell’, ‘Neighbourhoods Law’, ‘District Approach’, ‘NDC’) and one was a cluster RCT (‘Well London’). They took place in: Manchester, (Huxley and Rogers, 2004) Glasgow (Egan et al., 2010) and London (Phillips et al., 2014a) in the UK; deprived areas in the UK; (Walihery et al., 2015) Barcelona in Spain, (Mehdipanah et al., 2014) and; deprived areas in the Netherlands (Jongeneel-Grimen et al., 2016).

Many focussed on housing renovation (refurbishment and development to both the inside and outside of homes) and rehabilitation of social housing stock, and it was difficult to identify descriptions of changes to the public realm. ‘GoWell’ included relocation of residents and rebuilding of neighbourhoods but few descriptions of changes to neighbourhoods other than refurbishment to people’s homes. Urban regeneration across these studies also included social, economic and community based interventions for example: community engagement programmes, educational programmes, changes to tenancy agreements, public transport, and introduction of new facilities for people out of work or living on benefits and changes to the law (see Table 1).

3.3. Data collection tools and primary outcome

Data collection methods varied and included: routine data collection from household panel surveys (‘GSW Philadelphia’, ‘GSW Portland’, ‘Neighbourhoods Law’, ‘Greening Vacant Lots’); (Kondo et al., 2015; Branas et al., 2011; Sandas, 2015; Mehdipanah et al., 2014) postal questionnaires (Well-London, Wythenshawe Regeneration) (49 50) and; face-to-face questionnaire completion by researchers visiting people in their homes (‘District Approach’, ‘DIY streets’, ‘Noise reduction’, ‘Street Parks’, ‘WIAT’) (Stansfeld et al., 2009; Curl et al., 2015; Ward Thompson et al., 2013; Jongeneel-Grimen et al., 2016; Skjoelved, 2001).

Outcomes relied largely on self-report and involved a range of tools. Three studies assessed mental health from single survey questions asking if people felt anxious or depressed (Phillips et al., 2014a), or stressed (rated on a scale of 0–10) (Kondo et al., 2015; Branas et al., 2011). Other studies used validated multi-item scales: the mental component scales of the 12 item Short Form, quality of life scale (SF-12 MCS) (Egan et al., 2013a) and the 36-item SP(36) also called the Mental health inventory 5 (MIH)(5) (Jongeneel-Grimen et al., 2016); the 12-
item General health questionnaire (GHQ) 12 (Phillips et al., 2014a; Huxley and Rogers, 2004; Mehdipanah et al., 2014); Health Satisfaction scale (Huxley et al., 2004); Warwick-Edinburgh Mental Well-being Scale (WEMBS), and; Revised Clinical Interview Schedule (CIS-R) and 28-item GHQ (Stansfeld et al., 2009).

3.4. Risk of bias

Risk-of-bias assessments, conducted on 13 studies for which outcome data were extracted, are summarised in Fig. 3. Considering risk of bias assessments on the mental health outcomes of ‘Well London’, ‘GSW Philadelphia’, Greening Vacant Lots, and ‘Districts Approach’, these data would appear to be robust. The cluster RCT, ‘Well London’, was rated ‘low’ risk of bias across all domains. Three of the controlled before-and-after studies (‘GSW Philadelphia’, ‘Greening Vacant Lots’, ‘District Approach’) scored well across most domains but without randomization the possibility of residual confounding persists and therefore were scored at ‘moderate’ risk of bias. Outcome data from the remaining nine controlled before-and-after studies should be read with caution as all were rated either ‘serious’ or ‘critical’ risk for ‘bias due to confounding’. “This was related to having a single or few intervention and control sites (‘Wythenshawe regeneration’, ‘Street Parks’, ‘GSW Portland’, ‘Noise reduction’); little adjustment for confounding (‘Street Parks’, ‘GSW Portland’, ‘WIAT’, ‘GoWell’, ‘NDC’, ‘Wythenshawe regeneration’, ‘DIY Streets’); or evidence of baseline imbalance (‘Neighbourhoods Law’, ‘GoWell’).”

All controlled before-and-after studies scored ‘low’ risk for bias for ‘selection of participants’ because selection of the groups of participants was not related to the intervention (or the effect of the intervention) and the outcome. Due to the nature of the interventions (changes in the built environment) we judged there was ‘low’ risk of intervention and control sites being ‘misclassified’ and ‘low’ risk due to ‘departures from intended interventions’. However, ‘Noise reduction’ was rated ‘serious’ for this domain as the intervention of interest was the introduction of the bypass but both control and intervention sites were potentially affected by the bypass. The effect of bypass was assessed indirectly in this study. For the same reason, it was impossible to define a target trial for this study.

Five controlled before-and-after studies provided longitudinal data: each was rated as ‘serious’ risk of bias for ‘Missing data’ as large numbers of people did not return questionnaires at follow up (NDC, ‘Noise reduction’, ‘GoWell’, ‘Wythenshawe regeneration’ and GSW Portland). The remaining studies adopted a repeated cross-sectional design which does not suffer from attrition due to losses to follow-up unless a cluster/site drops out (‘District Approach’, ‘Neighbourhoods Law’, ‘Greening Vacant Lots’, ‘GSW Philadelphia’, ‘WIAT’, ‘DIY streets’,

Fig. 1. Flow of studies through the review.
Table 1
Characteristics of included studies.

<table>
<thead>
<tr>
<th>Study name, Author, Year(s)</th>
<th>Location</th>
<th>Changes to the built environment: intervention description</th>
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<tr>
<td>Transport infrastructure</td>
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<tr>
<td>‘Noise Reduction’ (Stansfeld et al., 2009)</td>
<td>Clwyd, North Wales</td>
<td>Road bypass built Road bypass diverted traffic away from three towns and their main streets with ‘high noise’ from traffic.</td>
<td>None reported</td>
<td>Residents in nearby uncongested side streets with ‘low noise’ from traffic</td>
<td>Mean age (years, months) High noise group = 50 Low Noise group = 51.10 Gender (female %): High noise group = 55 Low noise group = 45; Ethnicity Not reported; Socioeconomic status % deprived High noise group = 67% Low noise group = 45%; Manual labour High noise group = 52% Low noise group = 58%; Crowded home High noise group = 0% Low noise group = 1%; Non-home ownership High noise group = 8% Low noise group = 3%; Unemployed</td>
<td>Adults (16 years or over) living in households on the main streets facing traffic before the bypass was built, and a control population living in quieter adjacent side streets were eligible to participate</td>
<td>Questionnaire data collected in all streets simultaneously Clinical Interview Schedule-Revised (CIS-R) interviews conducted in participants’ homes by researcher blinded to the General Health Questionnaire (GHQ) score of the participant which was conducted in the same month</td>
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<tr>
<td>‘CHCS’ Commuting and Health in Cambridge Study (Ogilvie et al., 2016; Ogilvie, 2011)</td>
<td>Cambridgeshire, UK</td>
<td>Cambridgeshire Guided Busway built Purpose-built track with guided bus technology for buses with accompanying maintenance track for cycling, walking, horse riding and emergency vehicles that links Cambridge with local towns and villages Intervention area defined as either 600 metre road network distance buffer around the stops along the urban sections of the Busway or larger areas encompassing the towns and villages along the rural sections of the route ‘Intervention participants’ lived within 30 km radius of Cambridge city centre and worked in areas of Cambridge served by the busway</td>
<td>None reported</td>
<td>Two areas, defined using home postcodes, of the city with no direct access to the busway and similar socioeconomic (SE) and spatial characteristics to urban parts of the ‘intervention’ area</td>
<td>Mean age (years) = % Gender (female %) = 68.5 Age (years %) &lt; 30 = 16; 30-39 = 28.6 40-49 = 25.9; 50-59 = 21.3; Over 60 = 76;</td>
<td>Regular commuters aged 16 years or older Participants recruited through work places across Cambridge</td>
<td>Written questionnaire delivered by post Participants who engaged in the enhanced activity monitoring also received face-to-face visits</td>
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<td>2 Improving green infrastructure</td>
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| ‘GSW Philadelphia’ ‘Green storm water Philadelphia’ (Kondo et al., 2015) | Philadelphia, USA | Introduction of green storm water infrastructure Installations that allow infiltration or storage of storm water including tree trenches, rain gardens, pervious pavement installations, bioswales, bump outs, a wetland and storm water basins | None reported | Control and intervention sites were randomly selected and matched in 4 sections of the city. Each intervention areas was matched with multiple control sites | Mean age (years) = % Gender (female %) = 69.7 Age (years %) < 30 = 17; 30-39 = 27.8 40-49 = 24.9; 50-59 = 21.3; Over 60 = 76; | Authors state control and intervention sites were not statistically different in age, household income, % of households earning less than the federal poverty standard (Not described in detail) Median % of the population with less than a high school-level education was lower in the intervention group than control | Philadelphia residents who completed the South-eastern Pennsylvania Household Health Survey for Public Health Management Corporation selected using random digital dialing Survey repeated every 2 years with new cohort | (continued on next page)
<table>
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<tr>
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<tr>
<td>‘Green storm water Portland’ (Shandas, 2015)</td>
<td>Portland, USA</td>
<td>Introduction of green storm water infrastructure</td>
<td>Educational materials and workshops to engage community members in areas undergoing change</td>
<td>Two areas with no physical changes related to installation of stormwater facilities or educational materials about stormwater infrastructure</td>
<td>Residents of Portland who completed the survey before and after the intervention</td>
<td>All residents sent the survey by post at baseline (before intervention) and after 2 years</td>
<td>Follow-up survey sent 2 out of 8 neighborhoods that received the intervention</td>
</tr>
<tr>
<td>‘Greening vacant lots’ (Branas et al., 2011)</td>
<td>Philadelphia, USA</td>
<td>Regreening of vacant building plots</td>
<td>None reported</td>
<td>Three building plots matched to each plot for intervention within four sections of the city</td>
<td>Philadelphia residents who completed the Southeastern Pennsylvania Household Health Survey for Public Health Management Corporation using random digital dialling</td>
<td>Survey repeated every 2 years to new cohort</td>
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<tr>
<td>‘DIY Streets’ Paper 1 (Curl et al., 2015)</td>
<td>Multi-site, England, UK</td>
<td>Urban and landscape design improvements to engage community members in areas undergoing change</td>
<td>Engagement with the DIY street community process.</td>
<td>Areas where no changes were made matched with intervention areas on a one-to-one basis</td>
<td>Older adults (65 years or older) residents of Oxford</td>
<td>Survey administered by door-to-door leafleting, community meetings and information sessions</td>
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<tr>
<td>'DIY streets' Paper 2 (Ward Thompson et al., 2014)</td>
<td>Multi-site, England, UK</td>
<td>See above</td>
<td>See above</td>
<td>Streets which did not receive an intervention that were matched to intervention streets</td>
<td>Mean age (years) Intervention = 75.92 Control = 74.11 Gender (female %): Intervention = 51 Control = 63 Socioeconomic status See DIY Street Paper 1 above Ethnicity See DIY Street Paper 1 above</td>
<td>See above</td>
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<tr>
<td>'Street parks' (Skjøveland, 2001)</td>
<td>Bergen, Norway</td>
<td>Street parks installed in urban residential streets</td>
<td>Authors describe “a new place” referring to a park that was built on previously unused land</td>
<td>Two areas: 1) already established street parks and 2) five streets like the intervention streets but without intervention</td>
<td>Adults mean age (years) = 35.6 Gender (female %) = 54 Living with a partner(%) = 47 Households with child aged 15 years or less (%) = 24 Employed and living in the area for a mean of 5.3 years (%) = 85</td>
<td>Residents living in intervention and control streets Up to three visits were made to retrieve questionnaires</td>
</tr>
<tr>
<td>'WIAT Woods in and around town' (Ward Thompson et al., 2013)</td>
<td>Glasgow, UK</td>
<td>Investment in sustainable management of woodlands and improved recreation facilities in deprived areas</td>
<td>Publicity about changes to the woods</td>
<td>Area eligible but did not receive the intervention</td>
<td>Age (years) Intervention = 47.04 Control = 42.6 Gender (female %)</td>
<td>Residents living within 500m of the green spaces eligible for WIAT intervention Random quota sampling framework used to match survey sample to the national 2001 census for age, gender, and socioeconomic group for each area</td>
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Physical interventions included rubbish removed and vandalism repaired Improvements to footpaths, signage and entrance gateways Trees and vegetation pruned and cleared

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<tr>
<td><strong>3. Urban regeneration</strong></td>
<td><strong>Neighbourhoods’ Law</strong> (Mehdipanah et al., 2014)</td>
<td>Llei de Barris, Barcelona, Spain</td>
<td>Urban regeneration in four neighbourhoods</td>
<td>Media and TV adverts, employment courses directed at women and immigrants, adult literacy and numeracy courses</td>
<td>Neighbourhoods matched to and in same districts as intervention but no intervention received</td>
<td>Majority age (years) 35-64, manual workers and employed</td>
<td>Adults (over 15 years) who completed the Barcelona Health Surveys</td>
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<td></td>
<td><strong>Wythenshawe regeneration</strong> (Huxley and Rogers, 2004)</td>
<td>Wythenshawe, Manchester, UK</td>
<td>Urban regeneration</td>
<td>Changes included tenancy from local authority to housing trust status</td>
<td>Regions matched with and neighbouring intervention region in South Manchester</td>
<td>Mean age (years) Intervention = 51 Control = 53; Gender (female%) = 48 Non-white (%); Employment = 6 Control = 2; Single people (%): Intervention = 31 Control = 21; Unemployed (%): Intervention = 4.4 Control = 3.9; Paid employment (%): Intervention = 44 Control = 37; Not working because of ill health (%): Intervention = 8 Control = 22; Home owners (%): Intervention = 43 Control = 56; Income (pounds): Intervention = £164.27 Control = £804.81; General Health Questionnaire (GHQ)-12 Intervention = 2.6 Control = 2.3</td>
<td>Residents selected randomly to receive postal questionnaire</td>
</tr>
<tr>
<td><strong>Well London</strong></td>
<td><strong>London</strong> (Phillips et al., 2014; Wall et al., 2009; Phillips et al., 2012)</td>
<td>London, UK</td>
<td>Multifaceted community based projects in deprived areas that included traditional health promotion, community engagement and changes to the built environment. Changes to the environment were curated through the “Healthy Spaces” project to develop existing and new sites for community gardens, allotments and play areas</td>
<td>Health walks, community arts projects and multifaceted themed project</td>
<td>Randomly allocated areas given no additional intervention</td>
<td>Mean age (years) Intervention = 38.4 Control = 38.0</td>
<td>People living in the most deprived areas of London</td>
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<tr>
<td>‘GoWell’ (Egan et al., 2016; Bond et al., 2013)</td>
<td>Glasgow, UK</td>
<td>Urban renewal and regeneration in disadvantaged neighbourhoods. Regeneration involving Glasgow housing association (GHA). £1.4 billion housing-led urban renewal programme over 10 years in 14 disadvantaged neighbourhoods. Programme included: housing demolition and improvement, new homes built, transformational regeneration, relocation of residents, new improved amenities, and services and community interventions.</td>
<td>‘Social programmes’ addressing social needs, debt management, employment support, antisocial behaviour, vulnerable residents support.</td>
<td>No official control group. But three investment levels were cited: Low, Medium and High economic investment. ‘Controlled experiment’: people who were relocated from a neighbourhood undergoing regeneration were compared to people who remained (Bond et al., 2013). Pragmatic control group of participants who in 2008 had not experienced demolition or housing improvement due to unexpected delays (Bond et al., 2013).</td>
<td>Gender (female, %)</td>
<td>One adult per household, sampled randomly from addresses in each study area.</td>
<td>Survey administered by face-to-face interview. Cross sectional survey data repeated over time and nested longitudinal sample identified through retrospective matching.</td>
</tr>
</tbody>
</table>

Lower Investment = 67
Medium Investment = 61
Higher Investment = 56
Age (years, %) 16-39

Lower Investment = 21
Medium Investment = 32
Higher Investment = 26

Lower Investment = 39-64 years
Medium Investment = 48
Higher Investment = 39

Lower Investment = 26
Medium Investment = 32
Higher Investment = 35
Qualifications (%) Yes
Lower Investment = 15
Medium Investment = 18
Higher Investment = 19

None
Lower Investment = 86
Medium Investment = 81.8
Higher Investment = 81.3

Education (%) Yes
Lower Investment = 14.6
Medium Investment = 18.2
Higher Investment = 18.7

Rented accommodation (%)
Lower Investment = 72.1
Medium Investment = 71.4
Higher Investment = 81.4

(continued on next page)
### Table 1 (continued)

<table>
<thead>
<tr>
<th>Study name, Author, Year(s)</th>
<th>Location</th>
<th>Changes to the built environment: intervention description</th>
<th>Additional components of the intervention</th>
<th>Control</th>
<th>Participants</th>
<th>Sampling strategy</th>
<th>Data collection methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>NDC ‘New Deal for Communities’ (Walthery et al., 2015; Beatty et al., 2008; Lawless et al., 2010)</td>
<td>Multi-site, UK</td>
<td>Urban renewal and regeneration £50 million spent on each of 39 most deprived areas of England, between 1998 and 2011. 11% spent on health. Modernisation of social housing, new homes built, ‘cleaning up’ public spaces and remodel residential environments Improvements to property exteriors, gardens and alleyways and energy efficiency Traffic calming schemes introduced</td>
<td>Community, crime, child support, education, worklessness, and health initiatives Areas with similar levels of deprivation as intervention areas and did not border each other No intervention received</td>
<td>Gender (female %) = 59.7; Mean age (years) = 46; Cohabiting % = 30.6; Non-White % = 23.3; Jobless household % = 43.1; Rent accommodation % = 58.8; NVQ 4 or 5 % = 13.4; In good self-reported health % = 40.4; Mean MHIS Score % = 71.4</td>
<td>Addresses within which households and one respondent age 16 or over selected at random completing national household panel survey People who provided data on at least two occasions</td>
<td>Survey administered by face-to-face interview</td>
<td></td>
</tr>
<tr>
<td>Districts Approach’ (Jongeneel-Grimen et al., 2016; Droomers et al., 2014)</td>
<td>Multi-site, Netherlands</td>
<td>Urban regeneration funding 5 billion Euros for 40 target districts in The Netherlands in five policy areas: unemployment, educational level, housing conditions, safety and social cohesion Improvements to footpaths, cycle paths, parks, gardens and green areas. Also Housing improvement, new homes built and, removal of rubbish</td>
<td>Social interventions aimed at employment and income, debt management, tax reduction, preventing school drop outs and to improve social cohesion/ support and social capital, social safety including reducing burglary, vandalism graffiti and increasing traffic safety Three districts (two matched with propensity scores, and one matched with the rest of the Netherlands)</td>
<td>Age (years) = 46.1 Gender (female %) = 52.8 Partner/married with children % = 35.5</td>
<td>Most 40 deprived districts in the Netherlands</td>
<td>Survey administered by face-to-face interview Repeated cross-sectional data from the Dutch Health Interview Survey</td>
<td></td>
</tr>
</tbody>
</table>
'Street Parks'). Eight controlled before-and-after studies (NDC, 'GoWell', 'Wythenshawe Regeneration', Street Parks, WIAT, DIY Streets and 'GSW Portland', 'Noise reduction') were rated 'serious' for 'Bias in outcome measurement' because participants reported subjective outcomes, were not blinded to intervention status and were probably aware of the hypothesis being tested. The remaining studies used routinely collected data so, although participants were not blinded, it was judged they would have been unaware of the hypothesis being tested (Eldridge et al., 2016).

Nine studies were rated 'moderate' risk of bias for 'selection of the reported result' because there was no protocol or pre-specified analysis plan ('District Approach', 'Greening Vacant Lots', GSW Philadelphia', GSW Portland', 'Neighbourhoods Law', 'Noise reduction', 'Street Parks', 'Wythenshawe Regeneration' and 'WIAT'). DIY Streets' reported very little aggregate data and we wrote to authors for additional information, and was rated at 'serious' risk of bias (Ward Thompson et al., 2014). 'NDC' and 'GoWell' were both rated 'low' risk of bias as they had protocols and reported outcomes in full (Walthery et al., 2015; Egan et al., 2013).

3.5. Mental health and well-being outcomes

3.5.1. Urban regeneration

Fig. 4 presents a forest plot of effect estimates reported or computed from these six studies. Where possible, we present subtotals across studies, although we remark that as such averages are based on two studies each no strong conclusions should be drawn from them. There was no strong evidence of an effect of urban regeneration interventions on mental health outcomes. 'Neighbourhoods Law' and 'District Approach' dichotomised their mental health scales grading people as having good or poor mental health. The proportion of participants with poor mental health in 'Neighbourhoods Law' was similar in the intervention group from baseline (0.180) to follow up (0.176), whereas it increased in the control group (0.138 at baseline to 0.173 at follow up). The proportion of people classified as having a mental disorder living in intervened districts of the 'Neighbourhoods Law' study was reduced at five years, with weak evidence suggesting a small beneficial effect for the intervention $SDID = -0.11$ (95% CI $-0.22$ to $0.01$), (Mehdipanah et al., 2014) but this study is at 'critical' risk of bias. When pooled with data from the 'District Approach' (3 years) (Jongeneel-Grimen et al., 2016) the overall effect was reduced to $SDID = -0.03$ (95% CI $-0.08$ to $0.02$). Pooled data from 'NDC' and 'Wythenshawe Regeneration' showed no effect on symptoms of mental health $SDID = -0.01$ (95% CI $-0.15$ to $-0.05$ to $0.04$). (Huxley and Rogers, 2004; Beatty et al., 2009a) In the one study where the majority of the intervention was focused on changes to the private, or home environment ('GoWell'), weak evidence of a small beneficial effect of the intervention was identified ($SDID = -0.13$, 95% CI $-0.26$ to $-0.01$). Egan et al. (2013) Results from the 'Well London' RCT, suggested no differences in mental health between intervened and non-intervened areas ($SDID = -0.01$, 95% CI $-0.15$ to $-0.01$).
In addition ‘Well London’ reported results adjusted for age, gender, ethnicity, education, employment and appropriate baseline values, which yielded no differences on the Warwick-Edinburgh Mental Well-being Scale between intervened and non-intervened areas (adjusted mean difference $-1.52$, 95% CI $-3.93$ to $0.88$) (Phillips et al., 2012b). Also, single-item questionnaire evidence from the ‘Well London’ RCT reported no evidence of a reduction in people feeling anxious or depressed, SDID $-0.01$ (95% CI $-0.06$ to $0.00$).

<table>
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<tr>
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<td>Cs</td>
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<td>LOW</td>
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<tr>
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<td>MODERATE</td>
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<tr>
<td></td>
<td>GSW Philadelphia</td>
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<td>LOW</td>
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<td>CRITICAL</td>
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<td>Improving road infrastructure</td>
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<td>SERIOUS</td>
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<tr>
<th>Intervention type</th>
<th>Study name</th>
<th>Data collection method</th>
<th>1. Bias arising from the randomization process</th>
<th>2. Bias arising from timing of follow-up participants</th>
<th>3. Bias due to deviations from the randomization relative to randomization</th>
<th>4. Bias due to missing outcome data</th>
<th>5. Bias in measurement outcomes</th>
<th>6. Bias in selection of the reported result</th>
<th>Overall risk of bias</th>
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<td>Urban regeneration</td>
<td>Well-London RCT</td>
<td>Cs</td>
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</table>

**Key:**
- Cs = Cross sectional (two waves of cross sectional data); L = Longitudinal data; RCT = Randomized controlled trial; GSW = Green storm water; NDC = New deal for communities; Reg = Regeneration.

**Fig. 3.** Assessment of risk of bias using ROBINS-I or Cochrane Risk-of-bias 2 tool.
3.5.2. Improving green infrastructure

There was no effect of improving green infrastructure on mental health measured as stress in a single-item health question in ‘Greening vacant lots’ and ‘GSW Philadelphia’ studies (Table 2) (Kondo et al., 2015; Branas et al., 2011).

3.5.3. Transport infrastructure

The CHCS (Ogilvie et al., 2016) measured mental health but did not directly compare the intervened and non-intervened areas. We were therefore unable to record a treatment effect for intervention versus control or complete a risk of bias assessment. Intervention and control areas were defined by proximity to the new busway. For mental health outcomes they analysed those using the new route for active commuting (cycling/walking), compared to those who did not. They report improved mental health in the active commuting group, however this effect attenuated when controlled for baseline mental health (SDID 0.06, 95% CI −0.05 to 0.18) (Ogilvie et al., 2016). ‘Noise reduction’ compared mental health of people who lived in streets with different levels of traffic noise following introduction of a bypass, but no differences were found (see Table 2) (Stansfeld et al., 2009).

3.6. Quality of life outcomes

3.6.1. Urban regeneration

There was little evidence of an effect of urban regeneration on quality of life outcomes. ‘Wythenshawe Regeneration’ reported evidence from a single item outcome scale and identified decreases in quality of life for both intervention and control groups, with an intervention group reporting a greater loss of quality of life, SDID = −0.11 (−0.21 to −0.01) (Huxley et al., 2004). ‘NDC’ reported ‘life satisfaction’ at baseline was higher in comparator areas than intervened areas (Walthery et al., 2015; Beatty et al., 2009a). Following adjustment for demographic and socioeconomic factors they found no change overall but reported subgroup analysis suggesting people with lower socioeconomic status (SES) experienced a decrease in life satisfaction compared to those in the control areas, while people with higher SES living in the intervened areas reported an improvement in quality of life compared to those in the control areas (Table 3) (Walthery et al., 2015). There was no effect of improving green infrastructure on mental health measured as stress in a single-item health question in ‘Greening vacant lots’ and ‘GSW Philadelphia’ studies (Table 2) (Kondo et al., 2015; Branas et al., 2011).

3.6.2. Transport infrastructure

The CHCS (Ogilvie et al., 2016) measured mental health but did not directly compare the intervened and non-intervened areas. We were therefore unable to record a treatment effect for intervention versus control or complete a risk of bias assessment. Intervention and control areas were defined by proximity to the new busway. For mental health outcomes they analysed those using the new route for active commuting (cycling/walking), compared to those who did not. They report improved mental health in the active commuting group, however this effect attenuated when controlled for baseline mental health (SDID 0.06, 95% CI −0.05 to 0.18) (Ogilvie et al., 2016). ‘Noise reduction’ compared mental health of people who lived in streets with different levels of traffic noise following introduction of a bypass, but no differences were found (see Table 2) (Stansfeld et al., 2009).

3.7. Quality of life outcomes

3.7.1. Urban regeneration

There was little evidence of an effect of urban regeneration on quality of life outcomes. ‘Wythenshawe Regeneration’ reported evidence from a single item outcome scale and identified decreases in quality of life for both intervention and control groups, with an intervention group reporting a greater loss of quality of life, SDID = −0.11 (−0.21 to −0.01) (Huxley et al., 2004). ‘NDC’ reported ‘life satisfaction’ at baseline was higher in comparator areas than intervened areas (Walthery et al., 2015; Beatty et al., 2009a). Following adjustment for demographic and socioeconomic factors they found no change
<table>
<thead>
<tr>
<th>Intervention type</th>
<th>Study name</th>
<th>Outcome measure</th>
<th>Timepoint</th>
<th>N Intervention/Control</th>
<th>Statistics as presented in the papers</th>
<th>Risk-of-bias Overall assessment</th>
<th>Direction of effect favours intervention control</th>
<th>Re-analysis using summary data from studies</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Improving green infrastructure</strong></td>
<td>Green storm water Philadelphia (Kondo et al., 2015)</td>
<td>Single item question Stress(^{a})</td>
<td>2 years</td>
<td>N/A</td>
<td>Adjusted(^{c}) difference in difference estimate for stress (SE) = − 0.01 (0.05) p = ns</td>
<td>Moderate</td>
<td>No effect</td>
<td>Not able to calculate</td>
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<tr>
<td></td>
<td>Greening vacant lots (Branas et al., 2011)</td>
<td>Single item question Stress(^{a})</td>
<td>7 years</td>
<td>4436/13308</td>
<td>Adjusted(^{c}) difference in difference estimate for Stress (\beta = -0.02 ) SE = 0.12 (R^2 = 0.68) p = ns</td>
<td>Moderate</td>
<td>No effect</td>
<td>Not able to calculate</td>
</tr>
<tr>
<td><strong>Urban regeneration</strong></td>
<td>Neighbourhoods Law (Mehdipanah et al., 2014)</td>
<td>GHQ – 12(^{d})</td>
<td>Baseline</td>
<td>274/504</td>
<td>Intervention Proportion poor MH = 0.180 (SD = 0.38) Control Proportion poor MH = 0.138 (SD = 0.345)</td>
<td>Critical</td>
<td>Favour intervention</td>
<td>− 0.11 (99% CI − 0.22 to 0.01)</td>
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<tr>
<td></td>
<td></td>
<td>GHQ – 12</td>
<td>11 years</td>
<td>398/823</td>
<td>Intervention Proportion poor MH = 0.176 (SD = 0.38) Control Proportion poor MH = 0.173 (SD = 0.378)</td>
<td>Critical</td>
<td>Favour intervention</td>
<td>− 0.11 (99% CI − 0.22 to 0.01)</td>
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<td>Wythenshawe regeneration (Huxley et al., 2004)</td>
<td>GHQ – 12</td>
<td>22 months</td>
<td>Total = 1344</td>
<td>MD 0.273 (95% CI − 0.134 to 0.481) p = 0.27</td>
<td>Critical</td>
<td>No effect</td>
<td>0.01 (99% CI − 0.06 to 0.09)</td>
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<td>Well London (Phillips et al., 2014)</td>
<td>GHQ – 12</td>
<td>4 years</td>
<td>1867/1886</td>
<td>Adjusted MD = − 0.01 (95% CI − 0.15 to 0.12) p = 0.4</td>
<td>Low</td>
<td>No effect</td>
<td>− 0.01 (99% CI − 0.15 to 0.12)</td>
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<td></td>
<td>GHQ – 12(^{d})</td>
<td>4 years</td>
<td>1867/1886</td>
<td>Adjusted risk ratio (1.15 (0.82-1.61)) p = 0.9</td>
<td>Low</td>
<td>No effect</td>
<td>Not applicable</td>
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<tr>
<td></td>
<td></td>
<td>Single item feeling anxious or depressed (%)</td>
<td>Baseline</td>
<td>2061/2046</td>
<td>Intervention mean = 17.8 (95% CI 13.6–22.0) Control mean = 18.7 (95% CI 13.6–23.6)</td>
<td>Low</td>
<td>No effect</td>
<td>− 0.01 (99% CI − 0.06 to 0.04)</td>
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<tr>
<td></td>
<td></td>
<td>Single item question feeling anxious or depressed (%)</td>
<td>4 years</td>
<td>1867/1886</td>
<td>Intervention mean = 9.0 (95% CI 6.4–11.5) Control mean 8.4 (95% CI 6.4–10.4)</td>
<td>Low</td>
<td>No effect</td>
<td>− 0.01 (99% CI − 0.06 to 0.04)</td>
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<td></td>
<td>Well London (Phillips et al., 2012)</td>
<td>WEMBS</td>
<td>4 years</td>
<td>Intervention n = 1792–1886 Control n = 1825–1876</td>
<td>Adjusted MD = − 1.52 (− 3.93 to 0.88) p = 0.2 Intervention mean = 58.7 (95% CI 56.4–60.5) Control mean = 60.1 (95% CI 58.3–61.9)</td>
<td>Low</td>
<td>No effect</td>
<td>− 1.53 (99% CI − 3.93 to 0.88)</td>
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<tr>
<td></td>
<td>District Approach (Jongeneel-Grimen et al., 2016)</td>
<td>MHI – 5(^{e})</td>
<td>3 years</td>
<td>1445/7173</td>
<td>Adjusted difference of regression slope estimate(^{b}) (0.00 (95% CI − 0.17) to 0.17)</td>
<td>Moderate</td>
<td>No effect</td>
<td>− 0.01 (99% CI − 0.06 to 0.05)</td>
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<td></td>
<td>GoWell (Egan et al., 2013)</td>
<td>SF12(MCS)</td>
<td>4 years</td>
<td>315/283</td>
<td>Intervention: Baseline mean = 47.97 Follow up mean = 49.22 b = 2.41 (SE = 1.17) Control: Baseline mean = 47.77 Follow up mean = 46.93</td>
<td>Serious</td>
<td>Favour intervention</td>
<td>− 0.13 (99% CI − 0.26 to − 0.01)</td>
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<td></td>
<td>NDC (Beatty et al., 2009)</td>
<td>MHI(5)</td>
<td>4 years</td>
<td>5499/458</td>
<td>MD 1.37 p = 0.122</td>
<td>Serious</td>
<td>No effect</td>
<td>− 0.01 (99% CI − 0.06 to 0.04)</td>
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(continued on next page)
Table 2 (continued)

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<tr>
<th>Outcome measure</th>
<th>Timepoint</th>
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<th>Type of evidence used</th>
<th>Direction of effect between intervention and control</th>
<th>Risk-of-bias Overall assessment</th>
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<tbody>
<tr>
<td>Noise reduction (Samuel et al., 2009a)</td>
<td>1 year</td>
<td>67/161 (high vs low noise)</td>
<td>MD = 0.6 (95% CI 0.2 to 0.8) p = 0.06</td>
<td>No effect</td>
<td>Critical</td>
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<td>CIS-R clinical interview schedule (Shandas, 2015)</td>
<td>1 year</td>
<td>Prevalence of common mental disorder at 1 year: high noise decreased by: 13.6% (95% CI 6.3 to 1.9) p = 0.007</td>
<td>MD = 1.2 (95% CI 0.8 to 1.6) p = 0.29</td>
<td>No effect</td>
<td>Critical</td>
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</table>

There is limited evidence for changes in quality of life from the ‘DIY streets’ multi-component intervention, which found that for intervened streets (those with improved traffic calming and landscaping), quality of life rose by an average by 3.82 points compared with a fall in the quality of life of people in the control streets of 7.25 points (Curil et al., 2015). This represents a SDID of ~ 0.54 (95% CI 1.23 to 0.15) or a medium effect size (DIY Streets, personal communication) but the broad 95% confidence intervals include the null and with range of size of effect from very small increase to substantial decrease in quality of life (Table 3).

3.8. Social isolation/inclusion outcomes

3.8.1. Urban regeneration

‘NDC’ measured four aspects of social ties with the community, and found no effect on problems with social relations, except to which people feel part of the community, extent that people are friendly in an area or the extent that people feel part of the local community (Beatty et al., 2009a).

3.8.2. Improving green infrastructure

Only ‘Street parks’ found any positive effect of improving green infrastructure on social isolation/inclusion outcomes. ‘Street parks’ increased ‘supportive acts of neighbouring’ (SDID = 0.68, 95% CI = 1.11 to 0.25) as measured in one of the four domains from the Multidimensional Measure of Neighbouring scale but also increased ‘neighbour annoyance’ (SDID = 0.73, 1.16 to −0.30) (Skjoelend, 2001). The authors also reported no effects on ‘social ties’ (SDID = 0.21, −0.63 to 0.19) and ‘neighbourhood attachment’ (0.12, −0.28 to 0.53) (Skjoelend, 2001). Using a Likert scale, ‘GSW Portland’ showed no effect of improving green infrastructure on whether people felt a neighbourhood to be friendly or sociable (Table 3) (Shandas, 2015).

3.9. Fear of crime outcomes

3.9.1. Urban regeneration

Both ‘Well London’ and ‘NDC’ (Beatty et al., 2009a; Phillips et al., 2014b) assessed fear of crime in single survey questions. ‘Well London’ reported no difference between intervened and control areas on whether people felt safe either in the day or at night (Phillips et al., 2014b). ‘NDC’ found intervention areas reported a larger decrease in fear of crime between 2002 and 2006 (adjusted difference in means = −0.67 p = 0.028) and people in the control groups reported feeling safer walking alone after dark compared with the intervention group (adjusted difference in means = −0.14 p = 0.02) (Table 3) (Beatty et al., 2009a).

3.9.2. Improving green infrastructure

‘GSW Portland’ found no effect of the intervention compared to control on a single item, fear-of-crime, measure. ‘Well London’ reported no difference between intervened and control areas on whether people felt safe either in the day or at night (Phillips et al., 2014b). ‘NDC’ found intervention areas reported a larger decrease in fear of crime between 2002 and 2006 (adjusted difference in means = −0.67 p = 0.028) and people in the control groups reported feeling safer walking alone after dark compared with the intervention group (adjusted difference in means = −0.14 p = 0.02) (Table 3) (Beatty et al., 2009a).

4. Discussion

We identified 14 diverse studies that met our criteria looking at

overall but reported subgroup analysis suggesting people with lower socioeconomic status (SES) experienced a decrease in life satisfaction compared to those in the control areas, while people with higher SES living in the intervened areas reported an improvement in quality of life compared to those in the control areas (Table 3) (Walthery et al., 2015).
Table 3
Social inclusion isolation, quality of life, fear-of-crime, safety and well-being outcomes.

<table>
<thead>
<tr>
<th>Outcome type</th>
<th>Intervention type</th>
<th>Study name</th>
<th>Outcome measure</th>
<th>Timepoint</th>
<th>N Intervention/Control</th>
<th>Statistics as presented in the papers</th>
<th>Direction of effect favours intervention or Control</th>
<th>Re-analysis using summary data from studies Standardised difference in difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social inclusion/isolation</td>
<td>Urban regeneration</td>
<td>NDC (Beatty et al., 2009a)</td>
<td>Extent feel part of local community</td>
<td>4 years</td>
<td>5499/458</td>
<td>Adjusted MD(^a) = −0.09 p = 0.159</td>
<td>No effect</td>
<td>Not able to calculate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NDC (Beatty et al., 2009a)</td>
<td>Extent people in area are friendly</td>
<td>4 years</td>
<td>5499/458</td>
<td>Adjusted MD(^a) = −0.0 p = 0.989</td>
<td>No effect</td>
<td>Not able to calculate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GSW Portland (Shandas, 2015)</td>
<td>Friendly or social neighbourhood</td>
<td>2 years</td>
<td>90/42</td>
<td>MD = −0.7</td>
<td>No effect</td>
<td>Not able to calculate</td>
</tr>
<tr>
<td>Improving green infrastructure</td>
<td></td>
<td>Street parks (Skjøveland, 2001)</td>
<td>MMN Supportive acts of neighbouring</td>
<td>2 years</td>
<td>38/37</td>
<td>Intervention mean = 2.47 SD = 0.90 p = m</td>
<td>FAVOURS intervention − 0.68 (95% CI − 1.11 to − 0.25)</td>
<td>Not able to calculate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>MMN Neighbourhood attachment</td>
<td>2 years</td>
<td>38/37</td>
<td>Intervention mean = 3.17 SD = 0.68</td>
<td>No effect</td>
<td>0.12 (95% CI − 0.28 to 0.53)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>MMN Weak social ties</td>
<td>2 years</td>
<td>38/37</td>
<td>Intervention mean = 4.45 SD = 1.24</td>
<td>No effect</td>
<td>−0.21 (95% CI − 0.63 to 0.19)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>MMN Neighbour annoyance</td>
<td>2 years</td>
<td>38/37</td>
<td>Intervention mean = 1.75 SD = 0.66</td>
<td>FAVOURS control − 0.73 (95% CI − 1.16 to − 0.30)</td>
<td>Not able to calculate</td>
</tr>
<tr>
<td>Fear of crime</td>
<td>Urban regeneration</td>
<td>NDC (Beatty et al., 2009a)</td>
<td>Fear of crime</td>
<td>4 years</td>
<td>5499/458</td>
<td>Adjusted MD(^a) = −0.67 p = 0.028</td>
<td>FAVOURS control − 0.82 (95% CI − 1.26 to − 0.39)</td>
<td>Not able to calculate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NDC (Beatty et al., 2009a)</td>
<td>Feel safe walking alone after dark</td>
<td>4 years</td>
<td>5499/458</td>
<td>Adjusted MD(^a) = −0.14 p = 0.020</td>
<td>FAVOURS control − 0.82 (95% CI − 1.26 to − 0.39)</td>
<td>Not able to calculate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Well-London (Phillips et al., 2012b)</td>
<td>Fear safe in the neighbourhood day</td>
<td>4 years</td>
<td>1792/1886</td>
<td>Intervention n = 1792 to 1886 Control n = 1825–1876</td>
<td>MD = 0.07 ns</td>
<td>No effect</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Feel safe in the neighbourhood night</td>
<td>4 years</td>
<td>1792/1886</td>
<td>Control n = 1825–1876</td>
<td>Intervention responses positive = 12% negative = 36%</td>
<td>FAVOURS control − 0.82 (95% CI − 1.26 to − 0.39)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Well-London (Phillips et al., 2012b)</td>
<td>Feel safe in the woodlands</td>
<td>3 years</td>
<td>90/42</td>
<td>MD = 0.07 ns</td>
<td>No effect</td>
<td>Not able to calculate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Eq (5d \text{VAS})</td>
<td>4 years</td>
<td>110/106</td>
<td>Control = 7.25 Intervention = 3.82</td>
<td>FAVOURS control − 0.01 (95% CI − 0.05 to 0.04)</td>
<td>Not able to calculate</td>
</tr>
<tr>
<td>Quality of life</td>
<td>Urban regeneration</td>
<td>NDC (Beatty et al., 2009a)</td>
<td>Single question Likert scale quality of life</td>
<td>4 years</td>
<td>5499/458</td>
<td>Adjusted MD(^a) = −0.06 p = 0.028</td>
<td>No effect</td>
<td>Not able to calculate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wythenshawe Regeneration</td>
<td>Health satisfaction</td>
<td>22 months</td>
<td>Total = 1344</td>
<td>MD = −0.108 (−0.209 to −0.008) p = 0.034</td>
<td>No effect</td>
<td>−0.01 (95% CI − 0.05 to 0.04)</td>
</tr>
<tr>
<td></td>
<td>DIY Streets (Ward Thompson et al., 2014)</td>
<td>Eq–5d VAS</td>
<td>Improved green infrastructure</td>
<td>3 years</td>
<td>56/40</td>
<td>Control = 7.25 Intervention = 3.82</td>
<td>FAVOURS control (unpublished data) Cohen’s effect size 0.54 (95% CI − 1.23 to 0.147)</td>
<td>Not able to calculate</td>
</tr>
</tbody>
</table>

Eq-5d VAS Euroqol-5D Visual Analogue Scale.
MD Difference in means.

MMN Multidimensional measure of neighbouring scale. The scale includes four domains 1) Supportive acts of neighbouring. As the score increases the supportiveness increases 2) Weak social ties. As score increases social ties improve. 3) Neighbourhood attachment. As the score increases neighbourhood attachment increases. 4) Neighbour annoyance. As the score increases the neighbourhood annoyance increases.

SD Standard deviation.

\(^a\) General linear models adjusted for key demographics and baseline variables.

\(^b\) Phillips et al provided a range of n for intervention and control because the analyses relied on complete case analyses, they did not provide a specific n for these difference in means.

\(^c\) Adjusted for age, gender, ethnicity, employment status, educational attainment and area summary health outcome measures.

\(^d\) Mann Whitney U test. Differences in variables within each site over time were analysed for significance.

\(^e\) Baseline imbalance (intervention group had lower health satisfaction than control) were taken into account in the calculation of standardised difference in difference.
interventions to the built environment and mental health and well-being of adults. Overall, we found a lack of evidence for an effect of built environment interventions on mental health and well-being outcomes. Small positive effects on fear of crime, social isolation/inclusion and quality of life outcomes were found in the ‘NDC’, ‘Street parks’ ‘DIY streets’ and ‘WIAT’ studies. However, apart from ‘NDC’, these studies received unfavourable assessments of risk of bias and their findings should therefore be interpreted with caution.

4.1. Heterogeneity

Interventions ranged from large-scale neighbourhood refurbishments to small ‘do-it-yourself’ parks in abandoned building sites. Furthermore, the description of the interventions was clear for some studies but problematic for others, especially when attempting to identify what changes had been made to the public realm in the large urban regeneration interventions. Study design also varied: we included one RCT and the rest of the studies were controlled before-and-after studies, some of which studied a longitudinal cohort of participants and others performed repeated cross-sectional surveys. The more robust studies included multiple intervention and control sites and studies set up prospectively before an intervention was implemented. Other studies were limited to opportunistic assessment of a single new development, and so were unable to adequately assess the impact of the intervention. Data collection methods also varied and included routine data collection from household panel surveys, postal questionnaires and face-to-face questionnaire completion by researchers visiting people in their homes.

4.2. Measuring outcomes

Outcomes for included studies depended largely on self-report and involved a range of tools. Some outcomes were measured using validated, multi-item scales and some involved single-item questions. Researchers use single-item questions to reduce time or the burden on participants, or where it is pragmatic to do so and, for example, using data from a national survey, with a single question on depression, enables large sample sizes. This variation also restricted opportunities for meta-analysis. However, there is evidence single-item, self-rated health questionnaires can correlate well with multi-item health questionnaires for mental health and other health related measures (Ahmad et al., 2014; DeSalvo et al., 2006). They are gaining traction as a means of measuring health (Bowling, 2005) and it would help future reviewers if there was some standardisation of these measures.

4.3. Risk of bias and limitations of the evidence

We used the RoB 2.0 for cluster RCTs and ROBINS-I tool to assess risk of bias of outcomes from the included studies (RoB 2.0 Tool, 2016; ROBINS-I Tool, 2016). This tool was developed for clinical studies, although an adaptation for controlled before-and-after studies and for public health interventions is currently in development. The ROBINS-I tool highlighted areas in which studies had been able to minimise bias, and ways in which the rating for risk of bias could be improved, some of which are discussed here.

Non-randomized, quasi-experimental study designs, such as controlled before-and-after studies can provide useful evidence if well designed. A key assumption for causal inference in controlled before-and-after studies is that the control group represents what would have occurred in the intervention group in the absence of the intervention. Therefore, the control group needs to be selected with care. However, defining exposure to changes to the environment can be difficult and problematic (Humphreys et al., 2016). An alternative may be to create a virtual control made out of weighted data from several areas, (de Vocht et al., 2017) individual computed distances (CHCS), individually calibrated exposures related to loci of activity or by observing actual exposure e.g., through use of portable electronic devices, or big data (Humphreys et al., 2016). Many of the CBA studies we included in this review contained only a single intervention and control site. When this is the case it is difficult to attribute any observed differences to the intervention rather than other site-specific variables. In studies with multiple sites, adjusting for important confounders in the analysis of the outcome (including socioeconomic status, age and gender) also reduces risk of bias and four of our studies did this for the mental health outcome.

The four studies that followed a longitudinal cohort of people all scored ‘serious’ risk of this bias as there were considerable missing data from baseline to follow-up often running to over 50% of the population and thousands of participants (‘GoWell’, ‘GSW Portland’, ‘NDC’ and ‘Wythenshawe Regeneration’) (Huxley and Rogers, 2004; Kondo et al., 2015; Jongeneel-Grimen et al., 2016; Egan et al., 2010). None of the studies reported the difference in numbers of people followed-up between intervened and control areas.

Although mental health outcomes are subjective and self-reported, and it is impossible to blind people to whether a change in the built environment has occurred, it is possible to blind people to the comparison being made or the hypothesis being tested. Studies using routinely collected data were rated at lower risk of bias, as we judged participants would not know they were in a study. This highlights a trade-off between the benefits of using routine data collection, say from household panel surveys which might include single-item questions on anxiety or depression, with multi-item mental health questionnaires administered by research personnel. Single item scores are gaining credibility as a useful alternative when multiple item outcome measures are not feasible (Ahmad et al., 2014; DeSalvo et al., 2006; Bowling, 2005).

Eight of the included studies adopted a repeated cross-sectional design. People might have moved (either into or out of a study area) for the second wave of data collection for reasons associated with the intervention. However, several studies compared features of the participants at both waves of data collection and found them to be similar, or performed sensitivity analyses excluding new-migrants, and found no effect on the observed results. In addition, recent research has indicated this self-selection hypothesis did not hold true for physical activity (James et al., 2015). A previous systematic review of the risk of bias in natural experiments of changes to the built environment on physical activity used the fore-runner of ROBINS-I the ‘Cochrane Risk of Bias Assessment Tool: for Non-Randomized Studies’ of Interventions, (ACROBAT-NRSI). They identified similar research priorities to this review that could improve methodological limitations of research (Benton et al., 2016) including: “better matching of control sites and more nuanced use of graded exposure; use of multiple control sites and controlling for confounding domains” (p14).

One of the five actions the WHO listed to improve health for people living in cities was to “Promote urban planning for healthy behaviours and safety” (World Health Organization, 2010), perhaps a more directed action, would be to embed robust research into all major town planning decisions to build a body of evidence. We also noted a dearth of studies looking at more modest changes to cities such as provision of footpaths, foot bridges, public lavatories, benches, etc. In addition, there are other questions to be considered which relate to the intervention and the context and implementation of the intervention. These issues are best investigated through robust process evaluation. However, consideration should also be given to what counts as robust enough evidence of effectiveness. Although we conclude that more robust studies are needed, we did find studies that reported small positive effects on fear of crime, social isolation/inclusion and quality of life outcomes. There also must be a call to evaluate, where there is evidence of promise, this may be a starting point for implementing stronger interventions with more robust evaluations in future.

We aimed also to review the impact of interventions on adults and older adults. However, in some studies the age of participants was not presented and given the limited evidence available a comparison of
effects by age subgroups was not possible.

4.4. Comparison to other literature

Existing systematic reviews on this topic included data from uncontrolled studies and consistently report an association between existing environment and mental health with poorer mental health in areas that are less green, perceived as having neighbourhood problems, or being unsafe (Won et al., 2016; van den Berg et al., 2015; Lee and Maheswaran, 2011; Lavin et al., 2006; Gong et al., 2016; Croucher et al., 2007; Thomson et al., 2006). Lorenc et al identified 14 controlled studies on street lighting and reported mixed evidence for a reduction in fear of crime; CCTV and multi-component interventions were not effective; and improvements to public areas showed an effect but they characterised the evidence as weak. They included one urban regeneration study and found no effect on fear of crime (Lorenc et al., 2013). The majority of these reviews also report that the evidence is weak, that causality can be implied rarely, and recognised the need for studies to investigate causal links using controlled data or more sophisticated study designs.

An important question arising from this review and previous research (Humphreys et al., 2016; Lawlor et al., 2003; Petticrew et al., 2005; Thomson, 2008) is why the evidence for the impact of interventions that are changes to the built environment is so poor, and what can be done to strengthen the evidence base? In synthesising the evidence, we have, necessarily, focused on bias relating to study design. And from that work, it appears that some study designs being used seem ill-suited to assess changes to the built environment. So the wider question is how do we promote the use of other types of analysis methods in this field? Natural experiments either with a suitable control or with good quality baseline and follow-up data can be used to assess changes to the built environment (de Vocht et al., 2017; Petticrew et al., 2005; Bernal et al., 2017; Bor et al., 2014). Interrupted time series can provide convincing evidence of effect if the following conditions are met. There are measurements at sufficient time points prior to the intervention so that the trend in the absence of intervention can be modelled. And there should be confidence that no other concurrent naturally occurring events could have influenced the outcome (Bernal et al., 2017). Regression discontinuity analyses can be designed to reduce the effects of confounding (if a small window around the cut-off on the allocation variable is used people on both sides of the cut-off can be considered to be similar) (Bor et al., 2014; O’Keefe et al., 2014). However we did not find studies using either of these designs. And in using them, researchers are likely to continue to face considerable methodological difficulties (Humphreys et al., 2016; Lawlor et al., 2003; Petticrew et al., 2005; Ogilvie et al., 2006).

It is important to note that mental health and well-being were not the primary outcome of most of the included interventions. Further consideration of the causal processes triggered by changes to the environment which could affect these specific outcomes is needed (Thomson, 2008; Parry et al., 2004). A greater understanding of these processes may help to understand why we found limited effects and help enhance the effects of similar interventions in the future. Indeed, causal pathway analyses may help understand which groups are a) exposed to the intervention or not (Humphreys et al., 2016; Mehdipanah et al., 2015) and b) whether certain groups are more susceptible to intervention effects (Parry et al., 2004; Mehdipanah et al., 2015). Including qualitative research nested within quantitative evaluations can help us identify how people interact with a change to the built environment and might be useful in determining which populations of people to study (Thomson, 2008; Mehdipanah et al., 2015).

Furthermore, measurable changes in population level mental health and well-being outcomes may take a long time to emerge.

Internationally, governments have been looking to promote health and reduce health inequalities through neighbourhood renewal and regeneration initiatives (World Health Organization, 2006; Barton et al., 2003; Mackenbach and Bakker, 2003). One of the most extensive urban regeneration projects ‘NDC’ reported that large scale area-based initiatives can lead to increased residential mobility (Beatty et al., 2009b) but increased mobility may indicate both positive and negative associations. While urban regeneration is associated with improved housing and/or provide better opportunities for employment, at the individual level, (Bailey and Livingston, 2007) mobility from deprived neighbourhoods may also result in weakened social bonds and cohesion (Laurence and Heath, 2008). In addition, residential mobility affects subgroups of the population to different extents, NDC found that residential mobility was greater in younger adults (16–34 years) and in areas with high levels of private rented sector housing (Beatty et al., 2009b). These complex relationships between urban regeneration and mobility may help to explain why it is difficult to determine changes in population level mental health in these studies. In this review eight of the fourteen studies used a cross sectional design with different people at follow-up, and all five longitudinal studies were rated at ‘serious’ risk of bias for missing data, highlighting both attrition and population turnover as key issues.

Interventions to modify the environment and address factors associated with mental health and well-being can result indirectly from government policy and directly through investment in local development and health initiatives. Policy makers and neighbourhood planners are urged to consider the ‘nature, drivers and consequences of residential mobility in deprived neighbourhoods’ and furthermore recommend a detailed knowledge of the local area when developing local initiatives (Beatty et al., 2009b).

To increase population levels of happiness, a feature of well-being, it is recommended planners implement designs that support opportunities for social interaction, feelings of safety in the environment and increase access to open green space (Barton et al., 2003; Pfeiffer and Cloutier, 2016). However, the public do not always agree with planner-anticipated benefits from changes to the environment (Ogilvie et al., 2010; Trayers et al., 2006; Mehdipanah et al., 2013). For example, in response to proposed changes to the environment designed to increase access and connection between residential areas and city centres, public perceptions of fear of crime and antisocial behaviour increased (Trayers et al., 2006; Mehdipanah et al., 2013).

4.5. Strengths and limitations of the review

We adopted rigorous systematic review methods and reported according PRISMA guidelines (Moher et al., 2009). We conducted a broad search of electronic bibliographic databases and grey literature. However, we restricted our search to publications written in English and this may have resulted in some studies being missed. This review focused on urban environments in high-income countries.

5. Conclusion

There is currently very little robust public health evidence from intervention studies that changes to the built environment can improve mental health, quality of life, social isolation or inclusion. Our review identified a relatively large number of studies and some of them were of reasonable quality, however they found a very small or no effect of built environment on mental health and wellbeing. This leads us to ask some serious questions: Can the effects of these interventions be measured using the methods at our disposal? Is measuring one ‘primary’ health outcome at one or two time-points too narrow? Perhaps research is needed to ask ‘why?’ these interventions appear to have little or no impact. Are the contextual backgrounds against which such outcomes are measured too nuanced and complex for us to take into account? Finding out ‘why?’ will likely require a different type of research and may need to go beyond the traditional comparative effectiveness research.
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Author contributions

SA, SG, JS and TM designed the study with input from JK, JLL, and SI. SA is the principal investigator and TM is the lead reviewer. JK, SI, SG are secondary reviewers. SG, SA, JK, AM and TM screened titles and abstracts and full-text papers and extracted data. TM, AM, SI, JK and JS applied the ROBINS-I. TM, JK, SA and SG wrote the first draft of the manuscript. Alison Richards developed the search strategy and conducted the searches. JLL provided statistical analysis and extracted data. All authors have critically revised the manuscript and approved the final version.

Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at https://doi.org/10.1016/j.healthplace.2018.07.012.

References


